MULTISCALE AIR QUALITY IMPACT FROM POWER PLANTS IN CITIES

F. Velay-Lasry[1], A. Albergel[1], W. Gao[3], F.H. Geng[3], G. Lacressonnière[1], M. Liu[2], A-S Saffre[1], B. R. Schwegler[2], Z.Q.Yu[3], Q. J. Zhang[1]

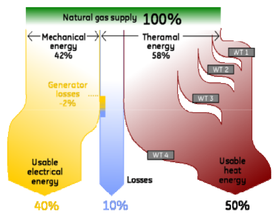
[1] ARIA Technologies, [2] Disney Research CHINA, [3] Shanghai Meteorological Bureau

Context

The use of cleaner fuels rather than coal, which is a main fuel source in China, for highly efficient power production is considered as one of the action for emission control.

Within this project, **the focus is on the use of a natural-gas-fired "combined cooling, heat and power" (CCHP) power plant.** Such an installation is already in service since the opening of the Disney Shanghai resort in order to provide full electricity, air conditioning, cold and hot water needs to the resort. And if such a system works efficiently for Disney resort, it can be imagined that in a near future CCHP can be used for residential areas, and thus **reducing the operation of coal power plants.** We show here how a **multi-scale modelling approach** allows determining the **benefits of the use of a CCHP installation**. The modelling is conducted with the WRF/CHIMERE regional models and with the lagrangian model PMSS for district scale effects. **Worst-case situations have been chosen for the study**: low wind speeds and elevated concentration levels.

The CCHP unit



Principle:
CCHP is a natural gas-fired, it produces 40% of usable electricity and 50% heat energy to be used for hot/cold water and heating

Conclusion

CCHP process is a real efficient technology to provide electricity, heating and cooling with a low emission budget especially comparing to a coal power plant. However, the main question raised here is the **displacement of the impacts**: if NOx concentrations have been substantially reduced over the region, the **CCHP plume impacts residential areas** as they are necessarily installed within the districts.

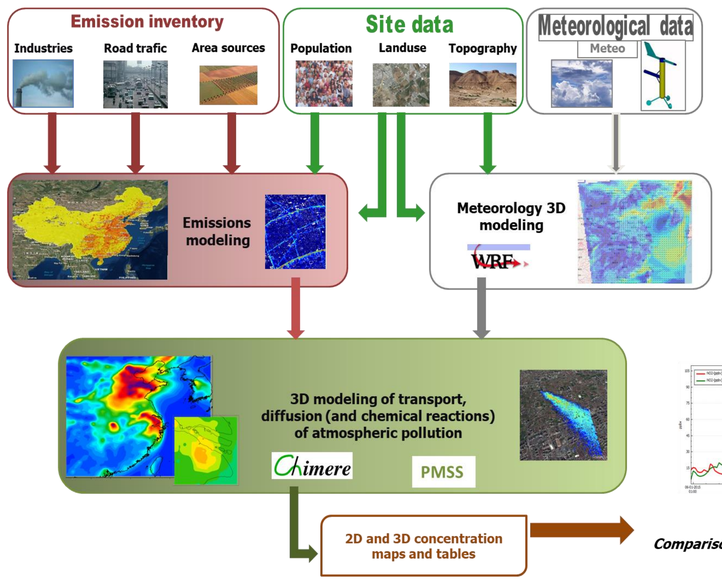
Model setup

WRF: (Weather Research and Forecast Model)
It is a supported 'community model", i.e. free and shared resource with distributed development and centralized support. Its development is led by NCAR, NOAA/GSD and NOAA/NCEP/EMP with partnerships at AFWA, FAA, NRL, and collaborations with universities and other government agencies in the US and overseas.

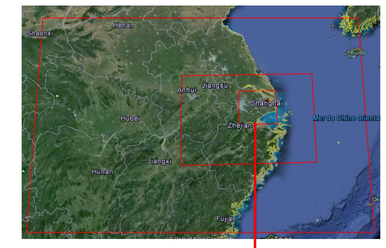
CHIMERE
The CHIMERE multi-scale model is primarily designed to produce daily forecasts of ozone, aerosols and other pollutants and make long-term simulations for emission control scenarios. CHIMERE runs over a range of spatial scales from the regional to the urban scale. It is developed and supported by Institut Pierre-Simon Laplace (CNRS) and INERIS.

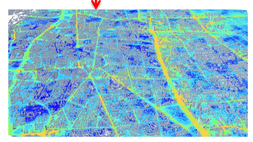
Micro-SWIFT
is a 3D diagnostic model which produces a mass and momentum consistent wind field using data from a dispersed meteorological network or from a less resolved meteorological model and taking into account a refined topography and the presence of buildings.

Micro -SPRAY
is a three-dimensional Lagrangian particle dispersion model developed by Arianet S.r.l. and Aria Technologies SA. Buildings are considered.

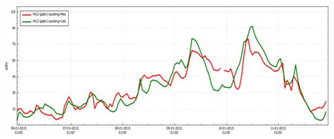


The 3 nested domains centered on Shanghai for the WRF/CHIMERE runs





District scale simulation over the Xujiahui district



CHIMERE model/obs comparison at Pudong station (NO_2)

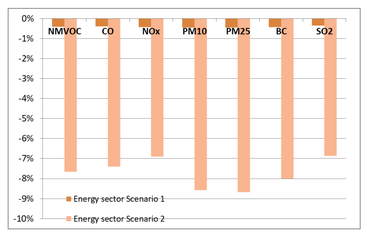
Emission scenarios

The purpose is to assess the **impact of the use of CCHP unit in Shanghai district as a replacement of the Waigaoqiao coal power plant** functioning.
Simulations have been performed at both regional and street scales.

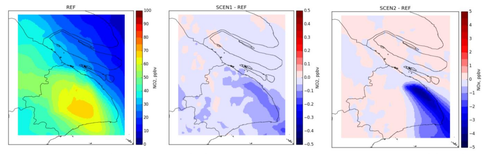
- At regional scale, two simulations have been performed based on different emission scenarios.
  - Scenario1: **one CCHP installation supplies the electricity needs of Xuhui district**. At the same time, we reduce by 5% the emissions from the Waigaoqiao coal power plant.
  - Scenario 2: **all Shanghai is supplied by CCHP installations**. We have estimated that 22 CCHP installations are needed to supply the electricity of Shanghai. Meanwhile, the coal power plant emissions are totally removed.
- **Simulations at street scale with a CCHP unit** only have been conducted in order to assess its impact on the Xuhui district

Regional scale impact

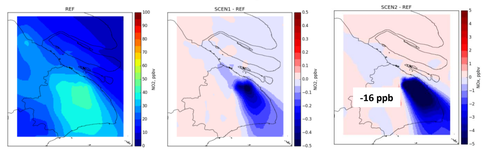
Emissions reduction for Scenario 1 and 2 for Energy sector



Considering the implementation of 22 CCHP units in Shanghai and suppressing the activity of the coal power plant the **impact is globally positive**, as all pollutants have their emissions reduced by **7 to 9% for the energy sector** for the scenario 2



Scenario result over NO2 daily average concentrations at ground level



Scenario result over NO_2 daily average concentrations in altitude (~250m)

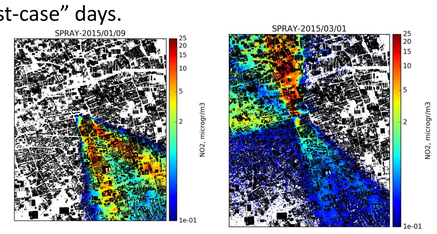
The dispersion modeling result shows that the 2 scenarios imply a reduction of NO_2 concentrations at the ground level due to the coal power plant emission reduction. The reduction is significant for scenario 2, and is even more important in altitude. The introduction of CCHP installations in Shanghai downtown doesn't affect much the air quality at the regional level as the concentration increase by less than 1µg/m³.

All pollutants see their emissions decreasing. The plume is impacted especially in altitude, meaning that **this action is beneficial for long-range transported pollution**.

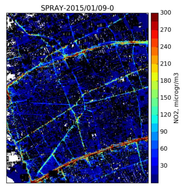
District scale impact

A simulation with CCHP emissions only was conducted over the district of Xujiahui. Its associated **NOx emissions reach 0.38 T/day**. In comparison, the **traffic emissions contribute for 4.2 T/day**.
Results are presented for 2 "worst-case" days.

Average concentrations in the CCHP plume are quite low (up to **10µg/m³**), but higher concentrations (25 µg/m³) are simulated very locally downwind the installation.



As a comparison, for this type of polluted day, the average NO_2 Concentrations from traffic can reach up to 300µg/m³ on the main roads



For these days, the coal power plant doesn't affect the Xujiahui district which is located south-westward. So **the pollution reduction seen from the regional scenarios is not reported on the street scale simulations**.