ATMOS'FAIR 2019

SLAM / AST&Risk :
Development of an innovative tool for 3D modelling of atmospheric dispersion, resulting from a collaboration between Ecole Centrale de Lyon and EDF

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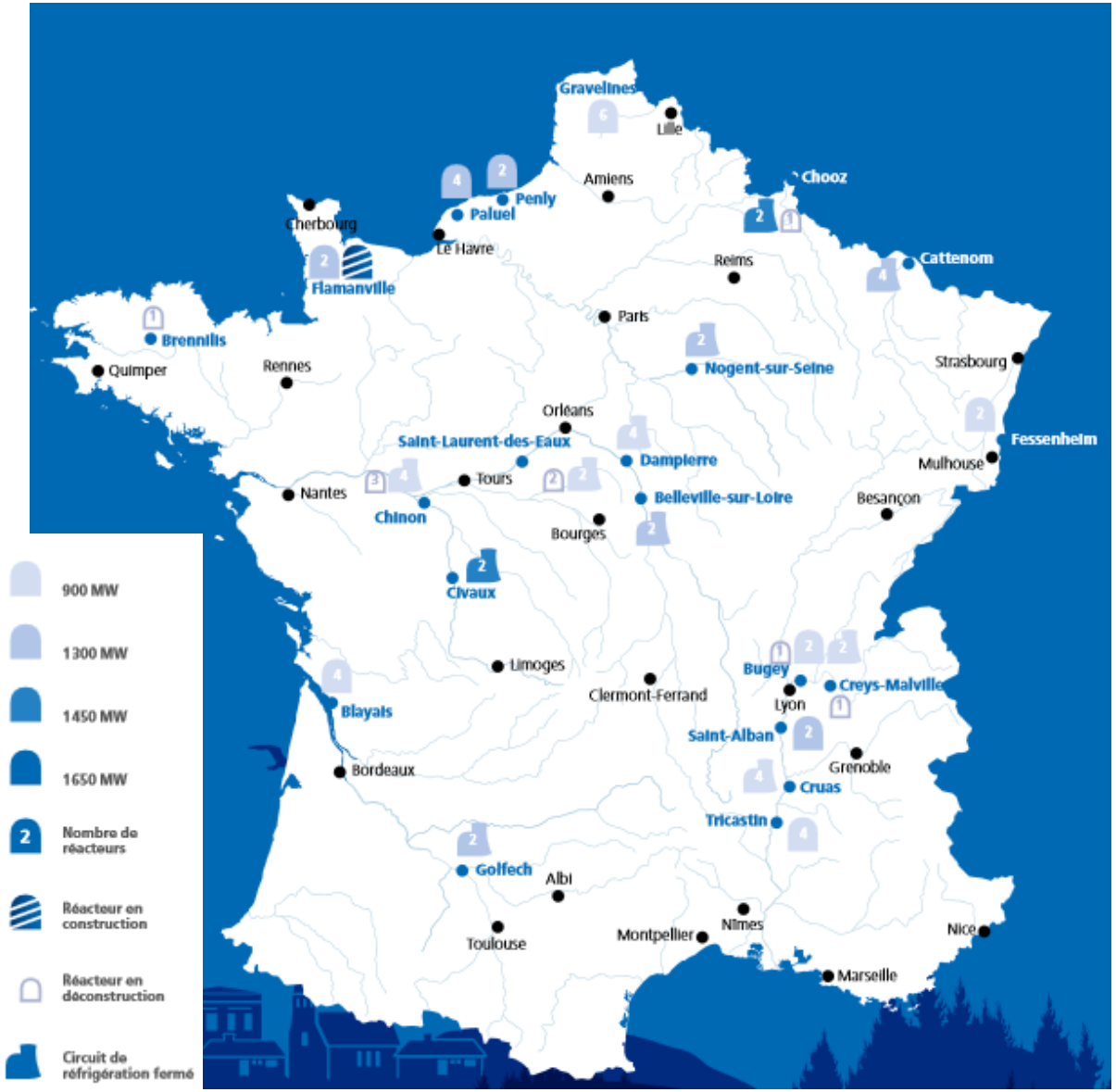
Summary

1. Context and end-user needs
2. Development of the SLAM/AST&Risk software
3. Main features and applications
4. Prospect
5. Conclusion

DIPDE

Division de l'Ingénierie du Parc,
de la Déconstruction et de l'Environnement



1 - Context and end-user needs

- DIPDE- ENV = Environmental engineering office for the French nuclear power plants
- Impact assessment for environmental authorization ➔ modelling atmospheric dispersion

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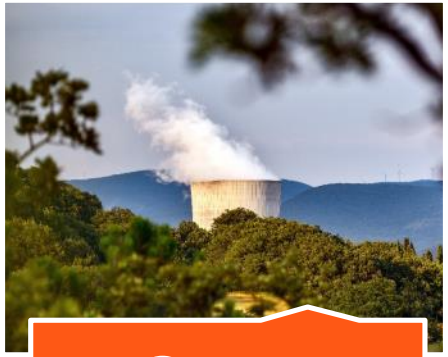

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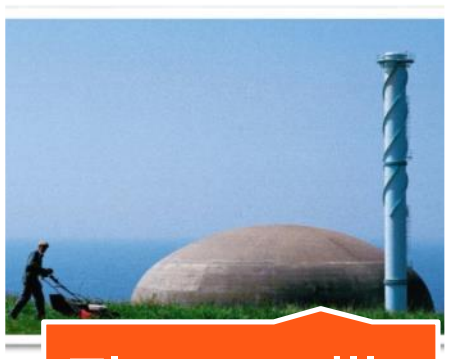


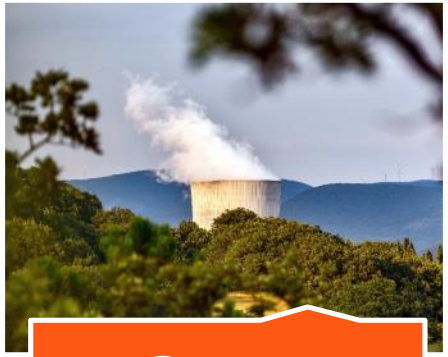
Flamanville

Paluel

1 - Context and end-user needs

- DIPDE- ENV = Environmental engineering office for the French nuclear power plants
- Impact assessment for environmental authorization ➔ modelling atmospheric dispersion
- Nuclear plants, complex topography sites and/or with high buildings ➔ sometimes simplified model for atmospheric dispersion (Gaussian type) are not optimized

Chooz



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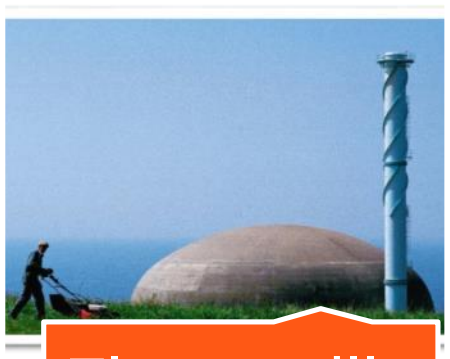

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1 - Context and end-user needs

- Needs :
  - Sophisticated atmospheric dispersion model for our environmental impact assessment
  - Engineering use (time, ability...)

- Beginning a collaboration between EDF and ECL in 2013 (long-term partnership for decades)

2 – Development of the Safety Atmospheric SLAM Lagrangian model / AST&RISK Atmospheric Simulation of Transport & Risk software

Computational Fluid Dynamics (CFD) for atmospheric dispersion

The main CFD steps:

1. Definition of the site of interest

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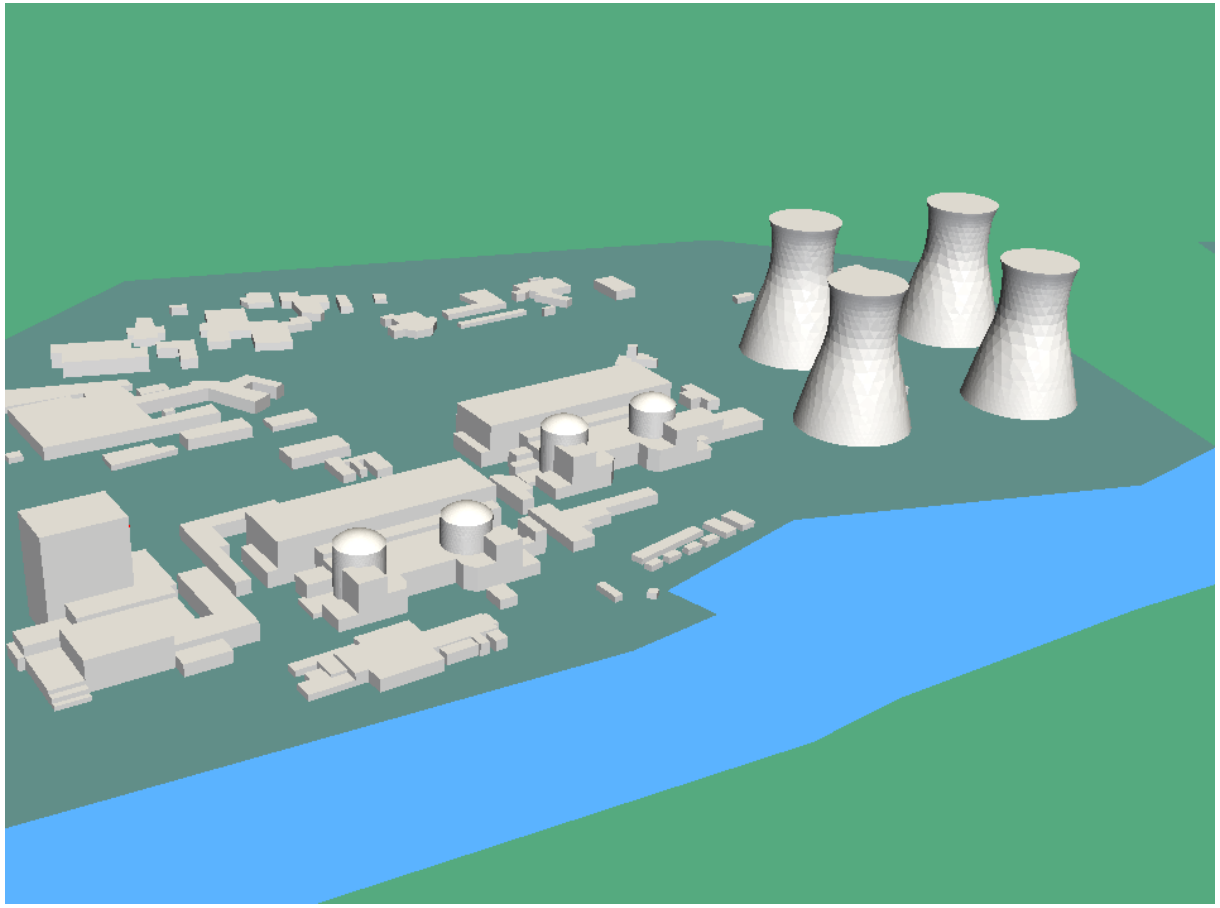
2 – Development of the Safety Atmospheric SLAM Lagrangian model / AST&RISK Atmospheric Simulation of Transport & Risk software

Computational Fluid Dynamics (CFD) for atmospheric dispersion

The main CFD steps:

1. Definition of the site of interest
2. CAD modelling of the geometry



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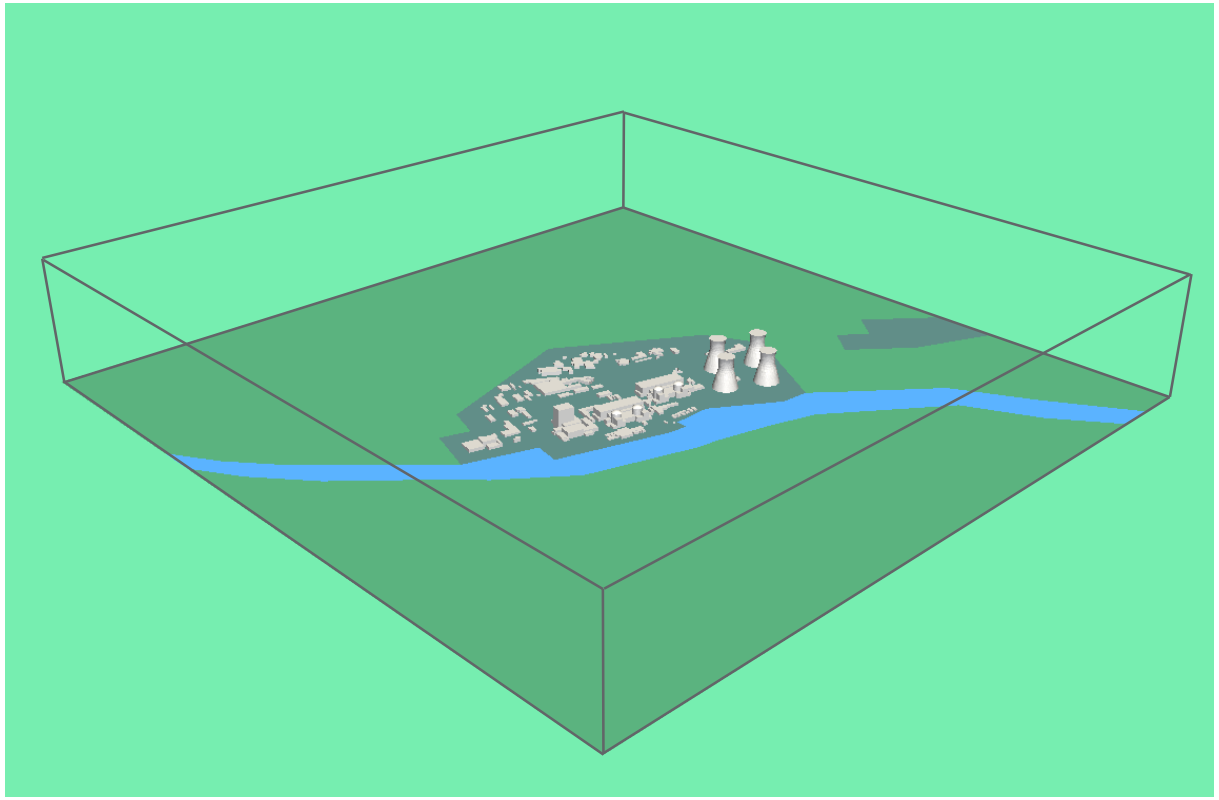
2 – Development of the Safety Atmospheric Lagrangian Model / AST&RISK Atmospheric Simulation of Transport & Risk software

Computational Fluid Dynamics (CFD) for atmospheric dispersion

The main CFD steps:

1. Definition of the site of interest
2. CAD modelling of the geometry
3. Delimitation of the domain

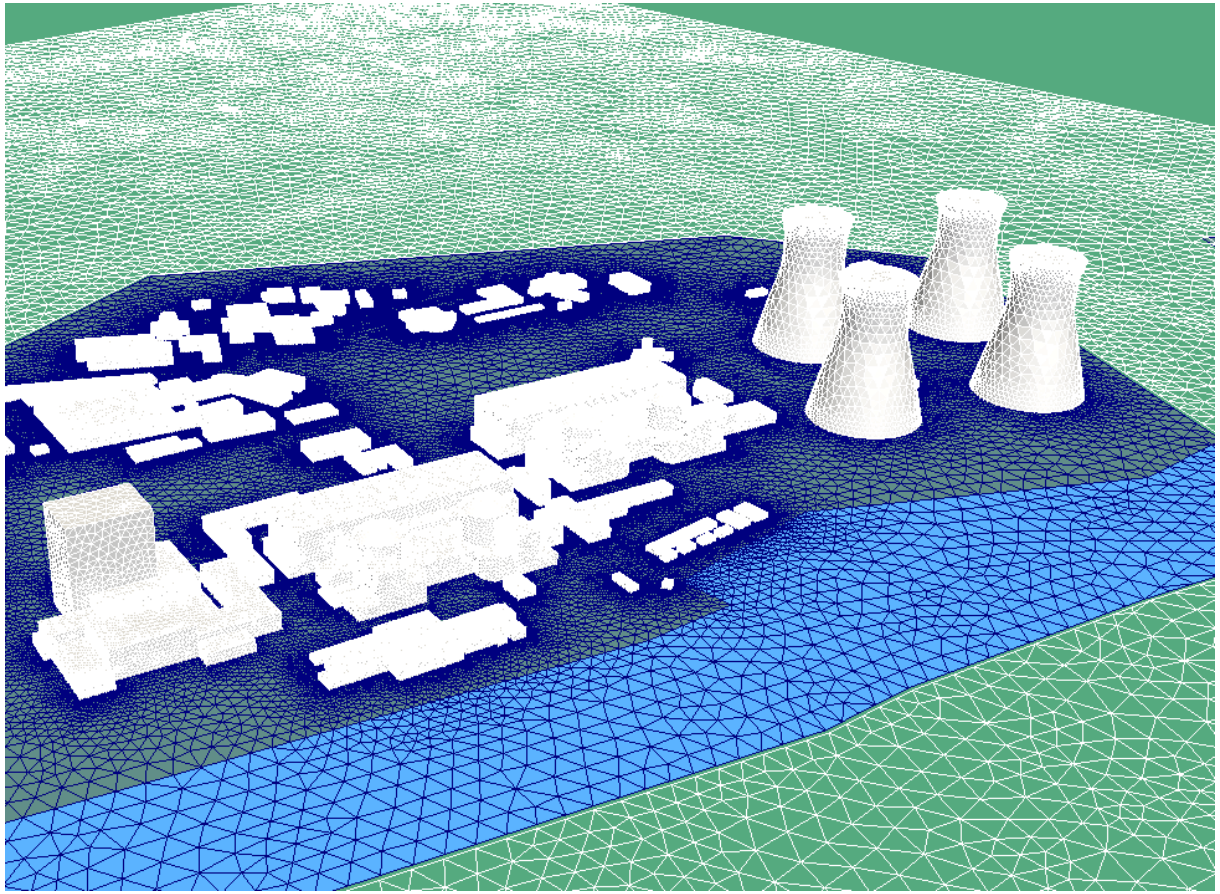


2 – Development of the Safety Atmospheric SLAM Lagrangian model / AST&RISK Atmospheric Simulation of Transport & Risk software

Computational Fluid Dynamics (CFD) for atmospheric dispersion

The main CFD steps:

1. Definition of the site of interest
2. CAD modelling of the geometry
3. Delimitation of the domain
4. Meshing surfaces



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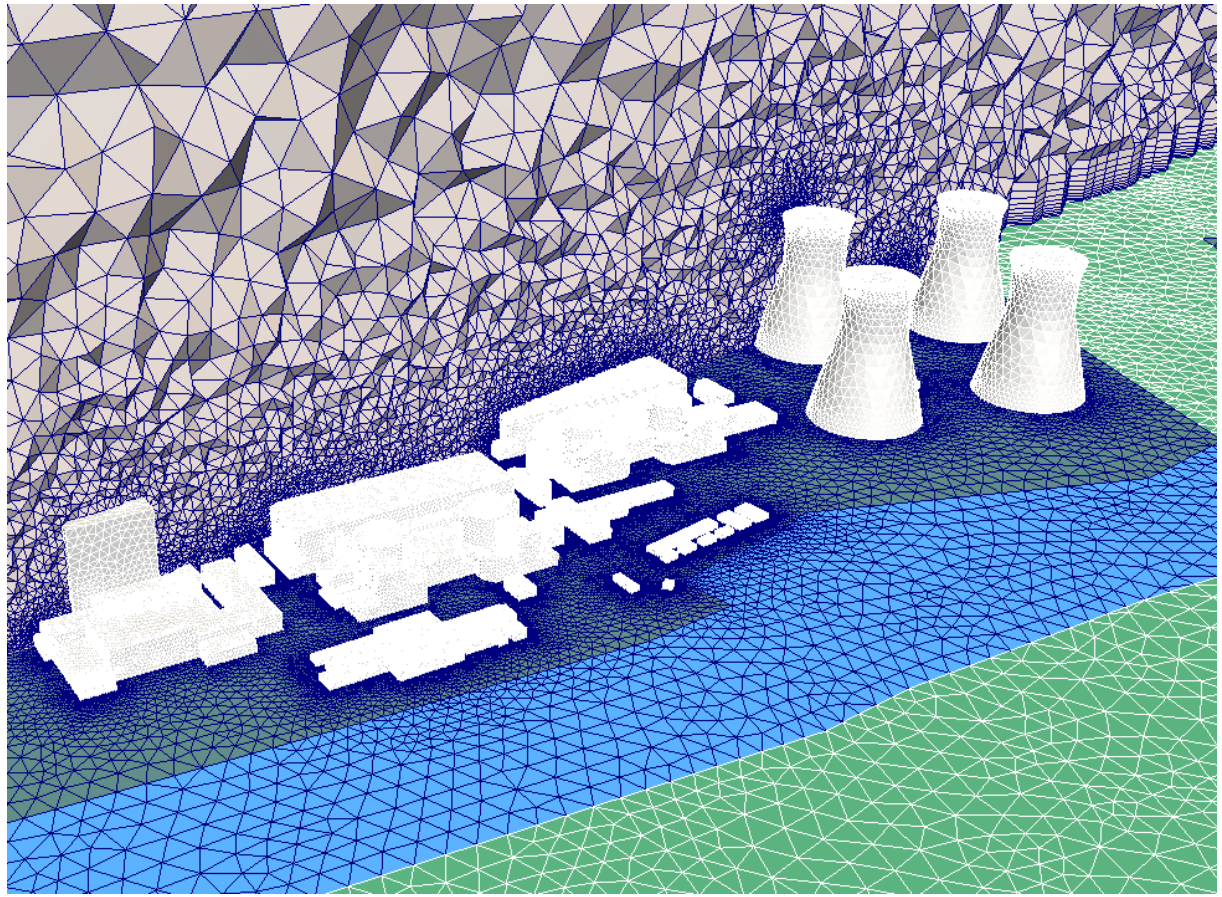
Computational Fluid Dynamics (CFD) for atmospheric dispersion

The main CFD steps:

1. Definition of the site of interest
2. CAD modelling of the geometry
3. Delimitation of the domain
4. Meshing surfaces & volume



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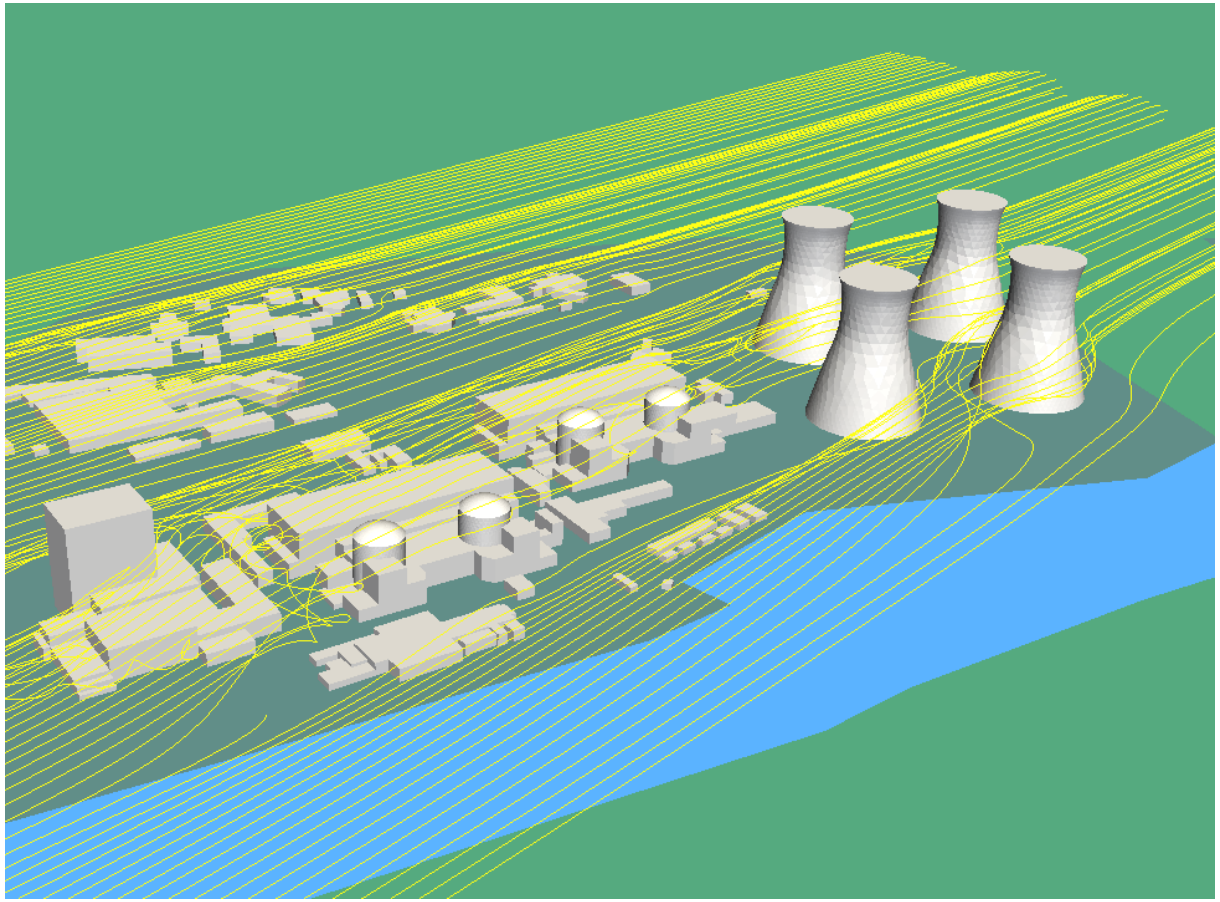
Computational Fluid Dynamics (CFD) for atmospheric dispersion

The main CFD steps:

1. Definition of the site of interest
2. CAD modelling of the geometry
3. Delimitation of the domain
4. Meshing surfaces & volume
5. Numerical solving of the physical equations

➔ Physical solution for the flow and dispersion of pollutants



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2 – Development of the Safety Atmospheric SLAM Model Lagrangian / AST&RISK Atmospheric Simulation of Transport & Risk software

Computational Fluid Dynamics (CFD) for atmospheric dispersion

Advantages of the CFD approach:

- High level of realism in the description of physical processes

Limitations of the "classical" CFD approach for operational use :

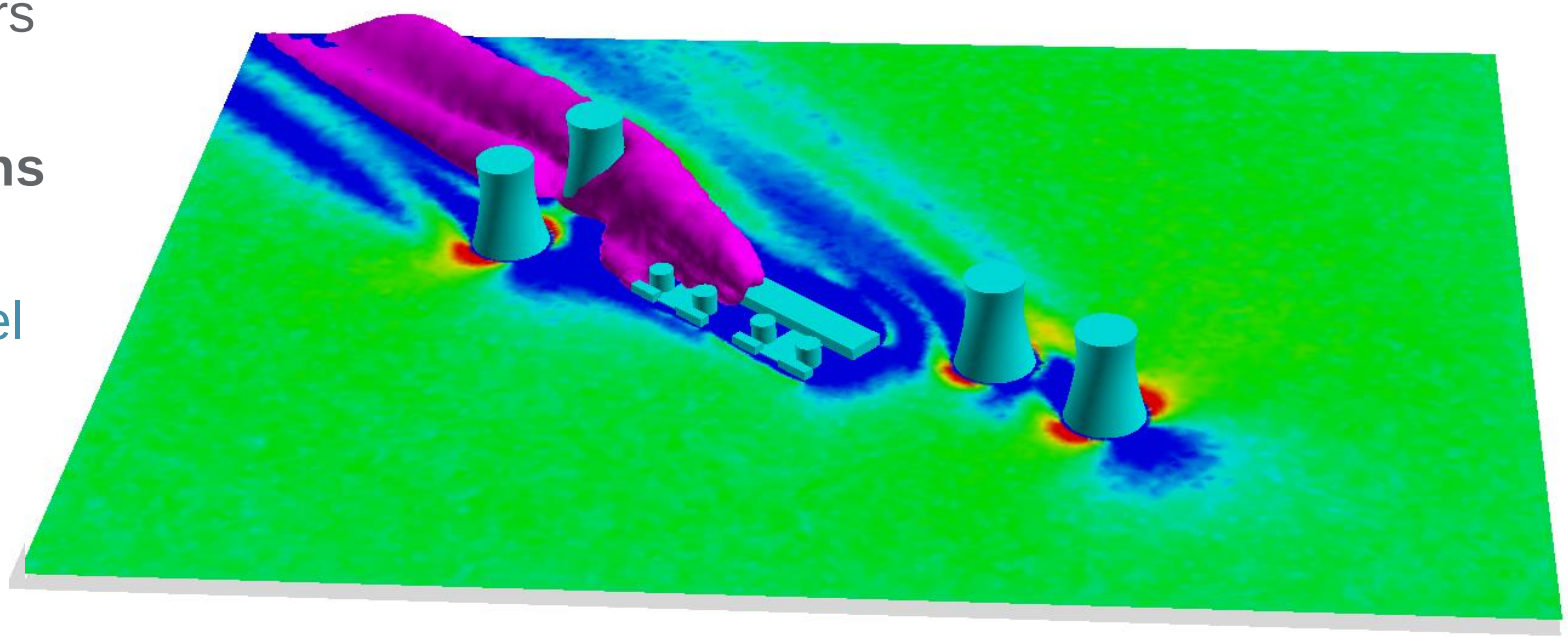
- CAD modelling and meshing require specific tools and skills and is time consuming
- Setup of atmospheric conditions of stability is tricky
- CPU time for one simulation is between 1 and 24 hours ➔ not applicable to simulate 5 years of hourly meteorological conditions (43 800 hours)

2 – Development of the Safety Atmospheric SLAM Lagrangian model / AST&RISK Atmospheric Simulation of Transport & Risk software

Principle of the Flow'Air 3D Atmospheric Air Flow Database Methodology methodology

Flow and dispersion on an industrial site depend on :

- **3D topography of the site**
  - ➔ constant for a given site
- **Upwind meteorological conditions in the boundary layer**
  - ➔ limited number of parameters
  - ➔ wind field database
- **Source and release conditions**
  - ➔ a priori unknown
  - ➔ operational dispersion model



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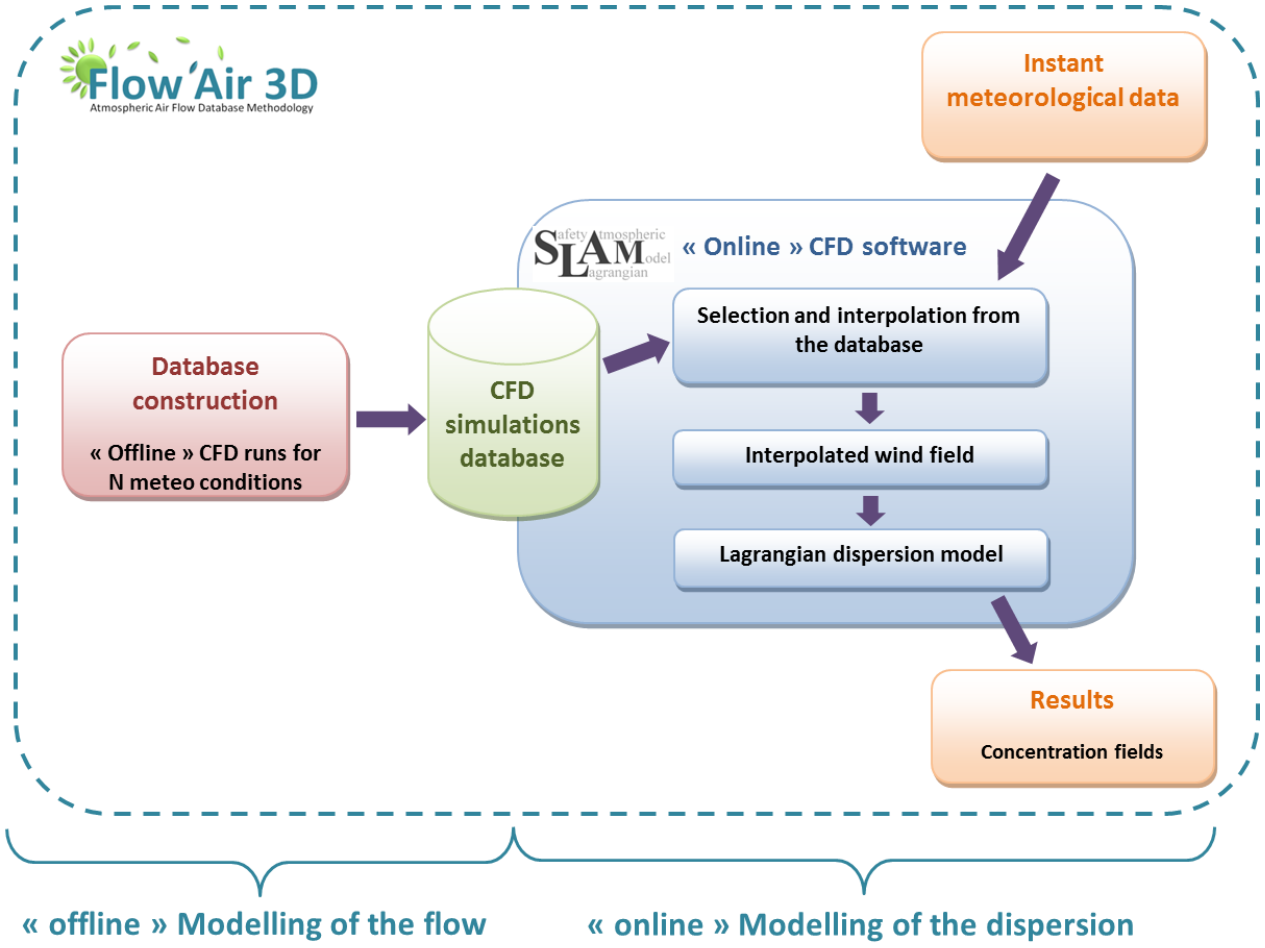
2 – Development of the Safety Atmospheric SLAM Model Lagrangian / AST&RISK Atmospheric Simulation of Transport & Risk software

Principle of the Flow Air 3D Atmospheric Air Flow Database Methodology methodology

Advantages:

- The most CPU time consuming and tricky steps of the CFD approach are performed offline, by CFD experts (between 10 and 30 work days)
- The end user's specificities (meteorology & sources conditions) are taken into account in the operational dispersion model SLAM
- CPU time of SLAM for one meteorology & sources condition = 1 to 2 min.



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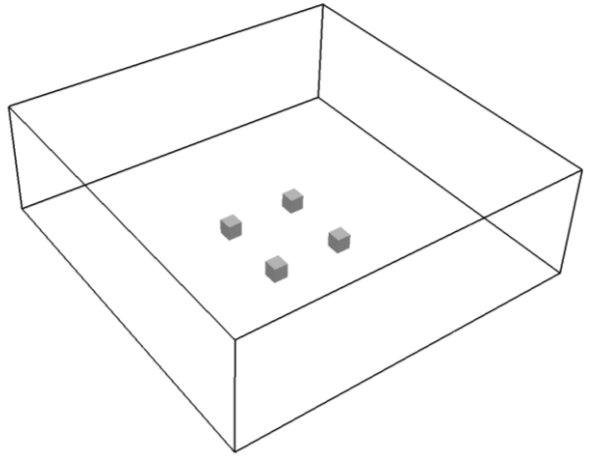
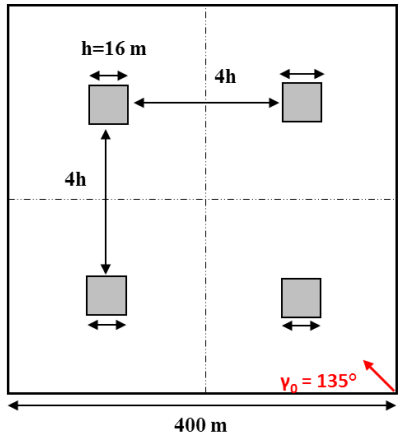
Principle of the Flow'Air 3D Atmospheric Air Flow Database Methodology methodology

Validation of the interpolation approach:

- Example of the wind direction
- Comparison between
  - the "reference" wind field
  - the interpolated wind field with different $\Delta\varphi$

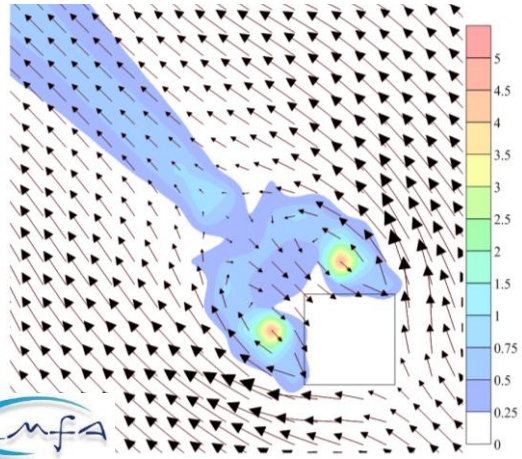




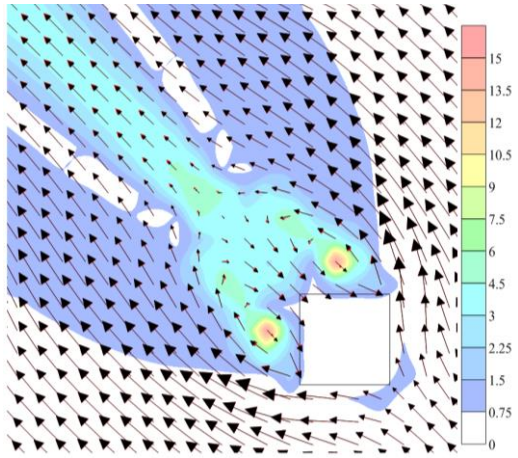
Interpolated wind field

Reference wind field

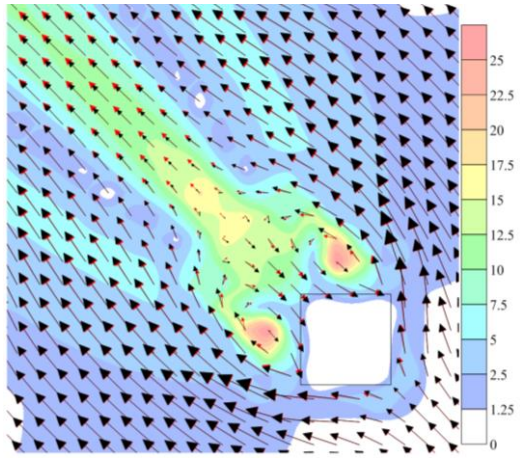
$\Delta\varphi$ = 5°



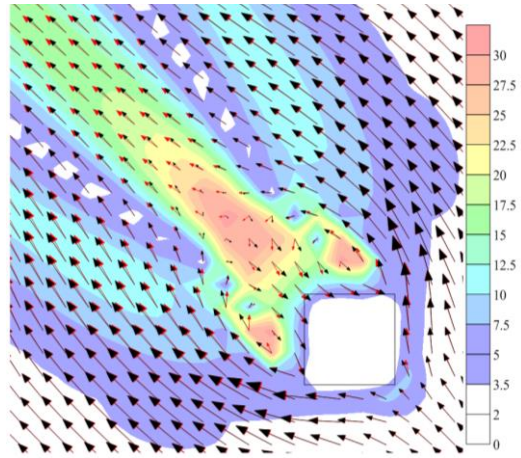
$\Delta\varphi$ = 10°



$\Delta\varphi$ = 20°



$\Delta\varphi$ = 30°



2 – Development of the SLAM / AST&RISK software

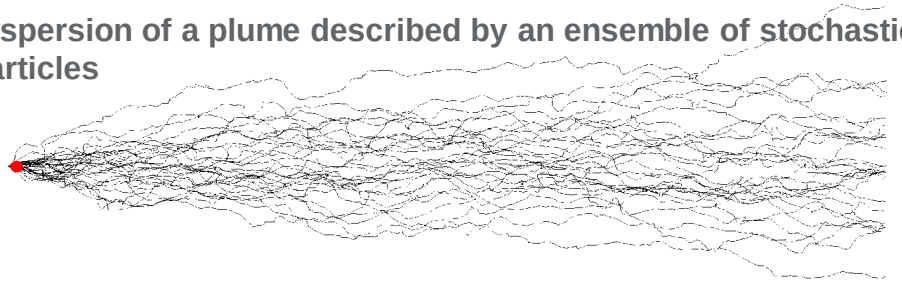
Overview of the SLAM Lagrangian dispersion model

Lagrangian particles dispersion model:

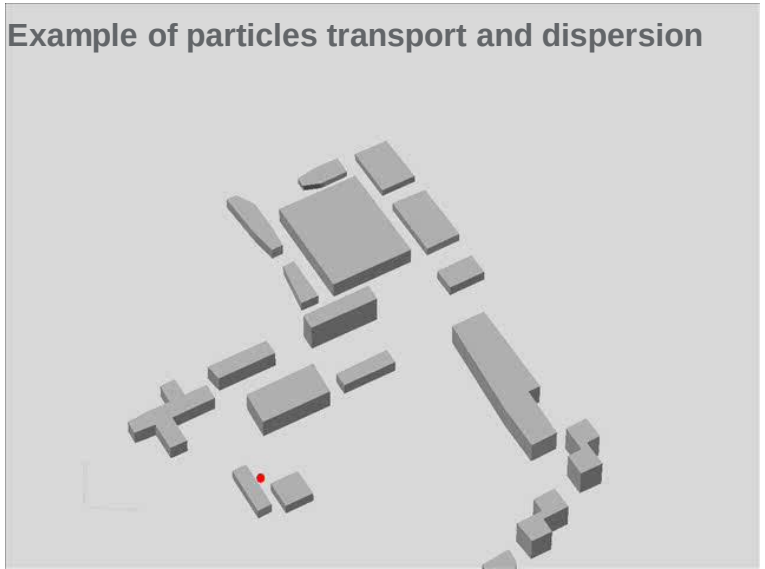
- Resolution of the Langevin stochastic differential equation
- Coupling with a database of CFD fields of wind and turbulence
- Meteorological preprocessor
- Jet and plume rise model
- Point / Surface / Volume sources
- Dry and wet deposition
- Radioactive filiation and decay

Stochastic trajectory of one individual particle

Dispersion of a plume described by an ensemble of stochastic particles



Example of particles transport and dispersion



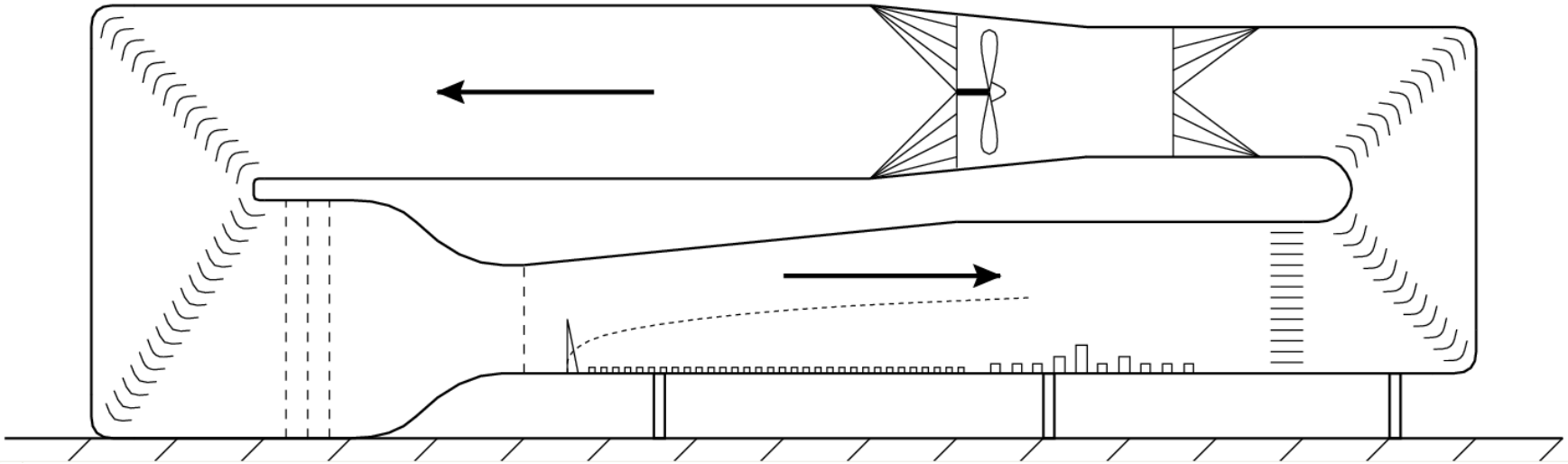
2 – Development of the SLAM / AST&RISK software

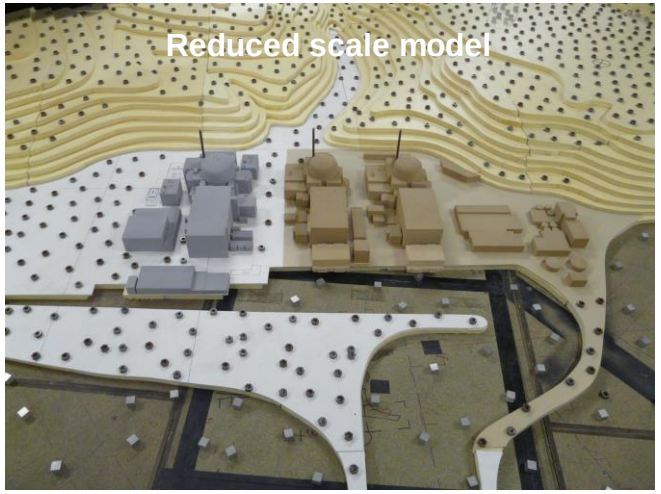
Overview of the SLAM Lagrangian dispersion model

Validation against wind tunnel experiments:

- Reduced scale model of a real EDF site (with relief & obstacles)
- Velocity and concentration measurements with a tracer gas
- Comparison between measurements and different modelling approaches

Atmospheric wind tunnel of the Ecole Centrale de Lyon





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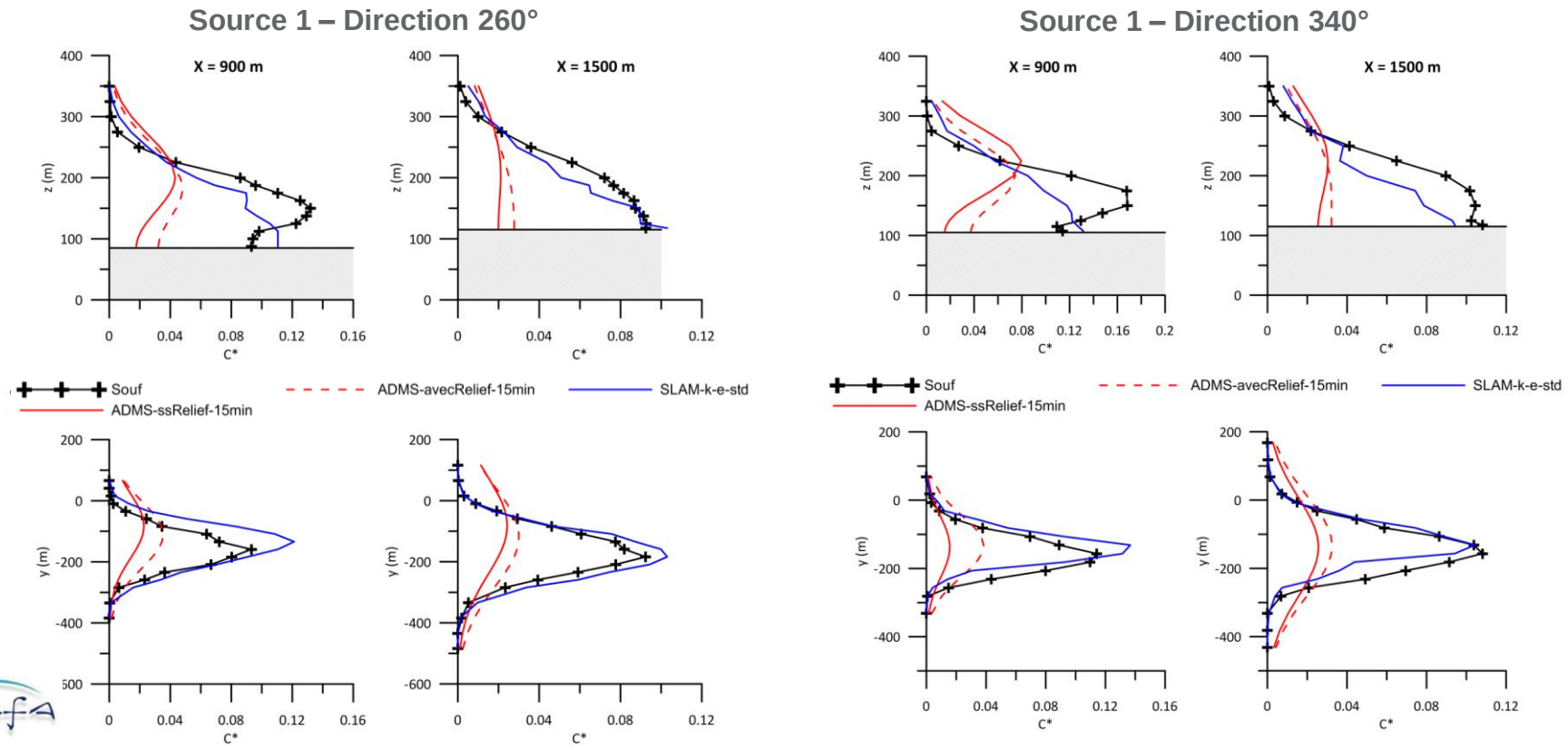
Overview of the Safety Atmospheric SLAM Lagrangian model Lagrangian dispersion model

Validation against wind tunnel experiments:



Measurements

SLAM

ADMS

2 – Development of the Safety Atmospheric SLAM Lagrangian model / AST&RISK Atmospheric Simulation of Transport & Risk software

Illustration of Safety Atmospheric SLAM Lagrangian model results

How to simulate 5 years of meteorological conditions ?

- 43 800 x 1 min. = 30 days of simulation
- Too long for the engineering context ➔ necessity to reduce more the CPU time

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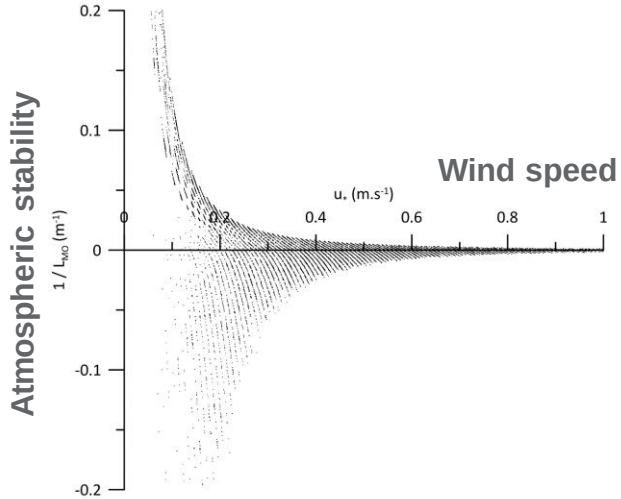
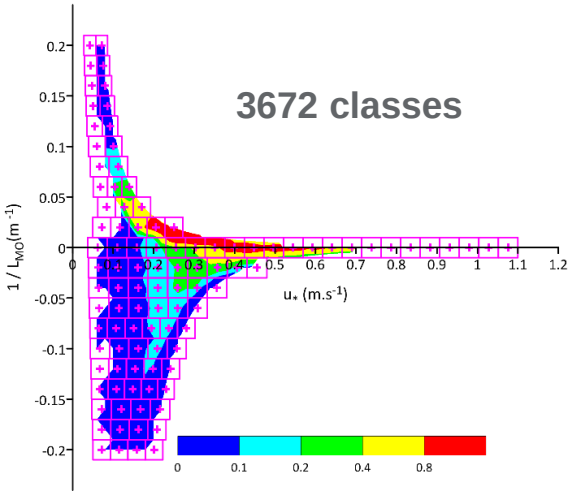
2 – Development of the Safety Atmospheric SLAM Lagrangian model / AST&RISK Atmospheric Simulation of Transport & Risk software

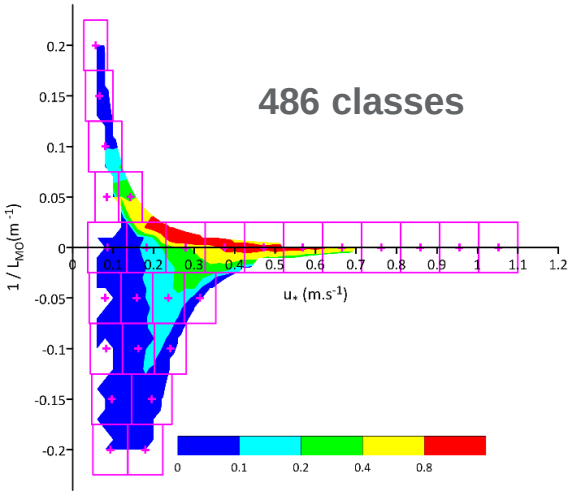
The AST&RISK Atmospheric Simulation of Transport & Risk classification approach

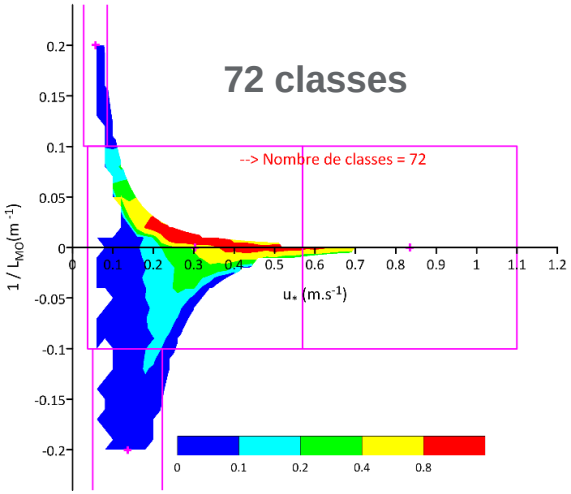
Classification approach of the meteorological conditions:

- Use of hourly weather data
- Weather preprocessing ➔ direction φ, velocity u*, stability 1 / L_{MO}
- Classification of the parameters space (φ, u*, 1 / L_{MO})
- Simulation of the dispersion for each class
- Calculation of statistics based on reduced distribution









2 – Development of the SLAM / AST&RISK software

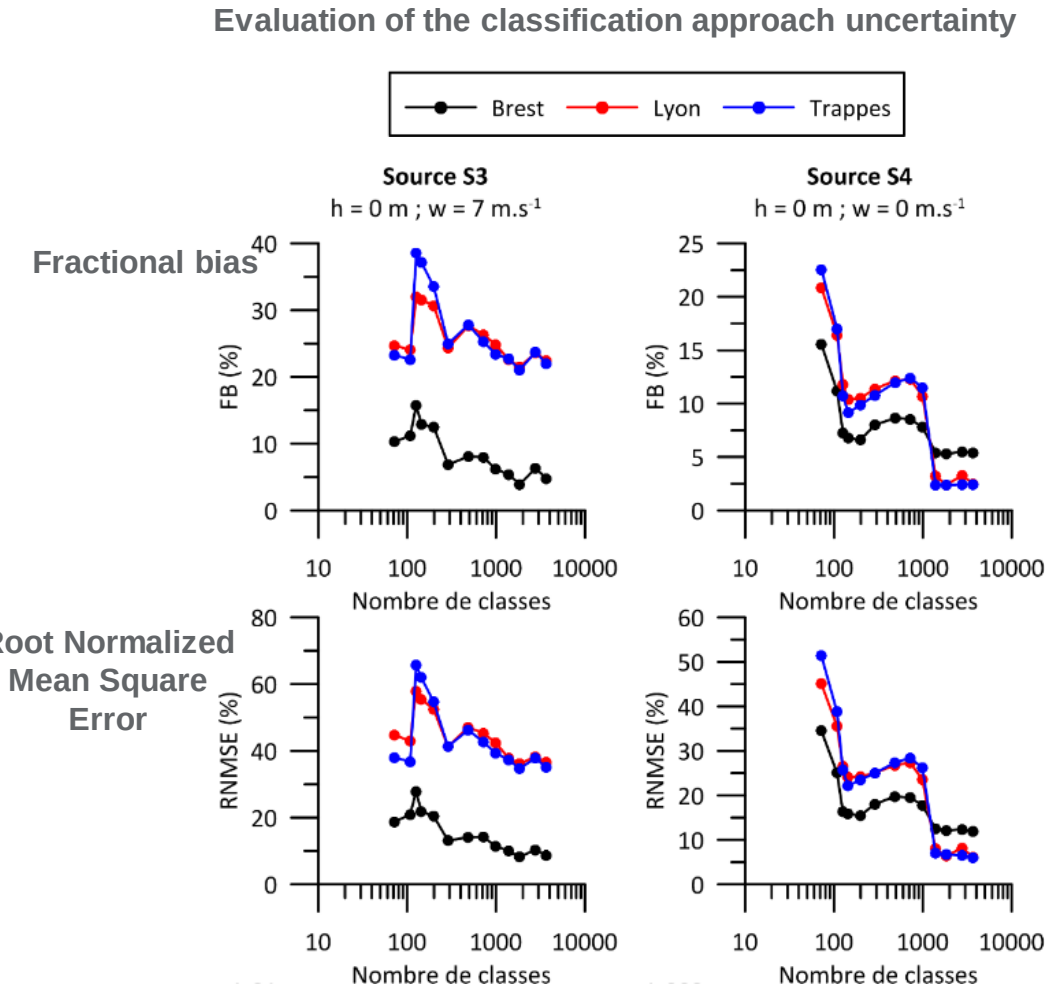
The AST&RISK classification approach

Sensitivity to the classification approach:

- Comparison of the classification statistics and the full 5 years hourly calculation
- Evaluation of the errors for 2 types of sources and ground level concentrations

Summary:

- 5 years hourly calculation can be calculated in a few hours, with a minimized uncertainty

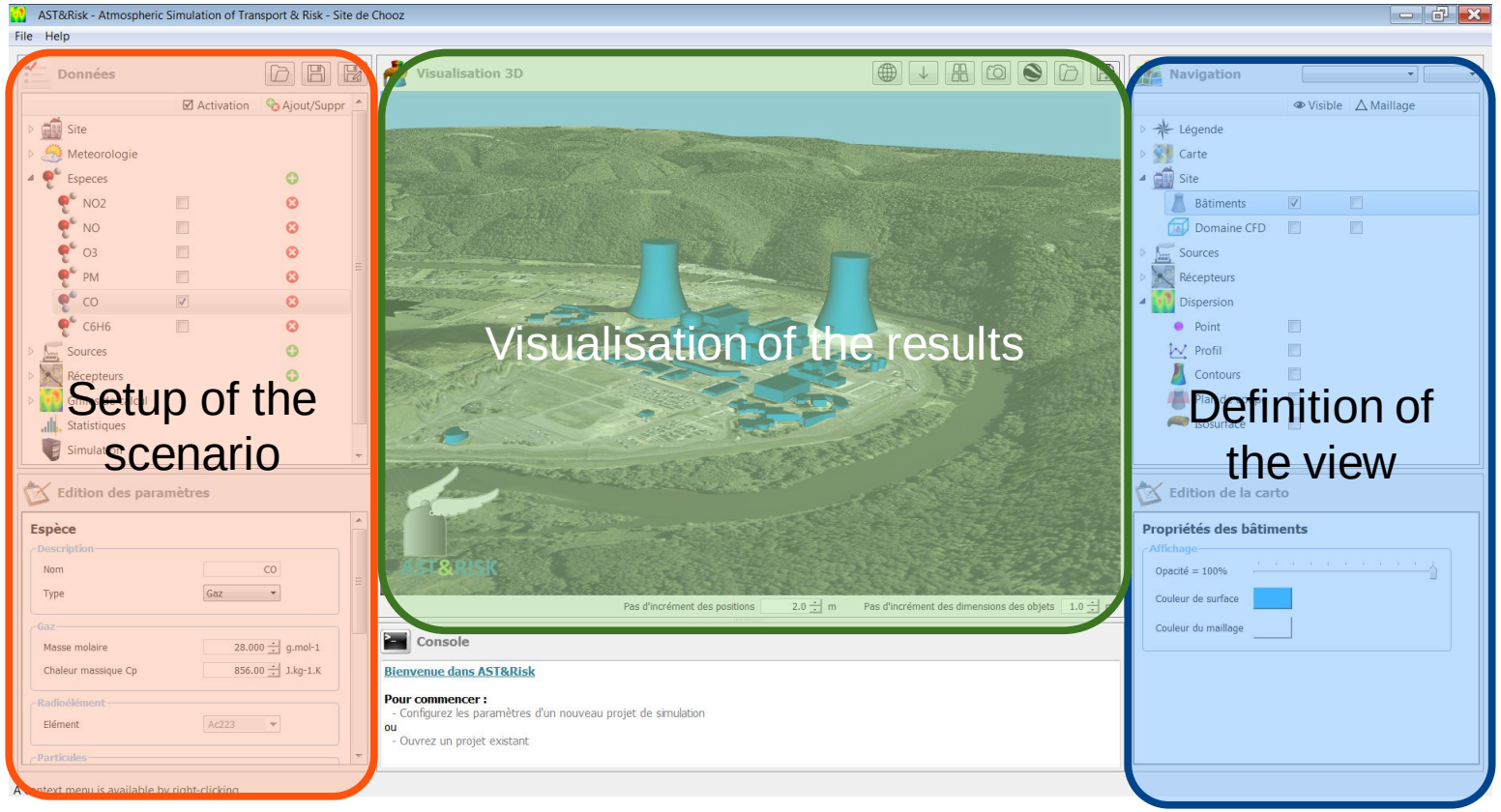


3 – Main features and applications

Graphical User Interface of the Safety Atmospheric SLAM Lagrangian model / AST&RISK Atmospheric Simulation of Transport & Risk software

- The “online” part of the methodology has been integrated in a user-friendly GUI

- The end-user can:
  - Setup his scenario
  - Run the calculation (1 meteo condition or a multi-years meteo data file)
  - Visualize and analyse the results
  - Export images and data



3 – Main features and applications

Graphical User Interface of the Safety Atmospheric Lagrangian Model / AST&RISK Atmospheric Simulation of Transport & Risk software

Visualization of the flow

Streamlines around buildings

3 – Main features and applications

Graphical User Interface of the Safety Atmospheric Lagrangian Model / AST&RISK Atmospheric Simulation of Transport & Risk software

Visualization of the flow

Wind field around buildings

3 – Main features and applications

Graphical User Interface of the Safety Atmospheric SLAM Lagrangian model / AST&RISK Atmospheric Simulation of Transport & Risk software

Visualization of the concentration field

Concentration field

3 – Main features and applications

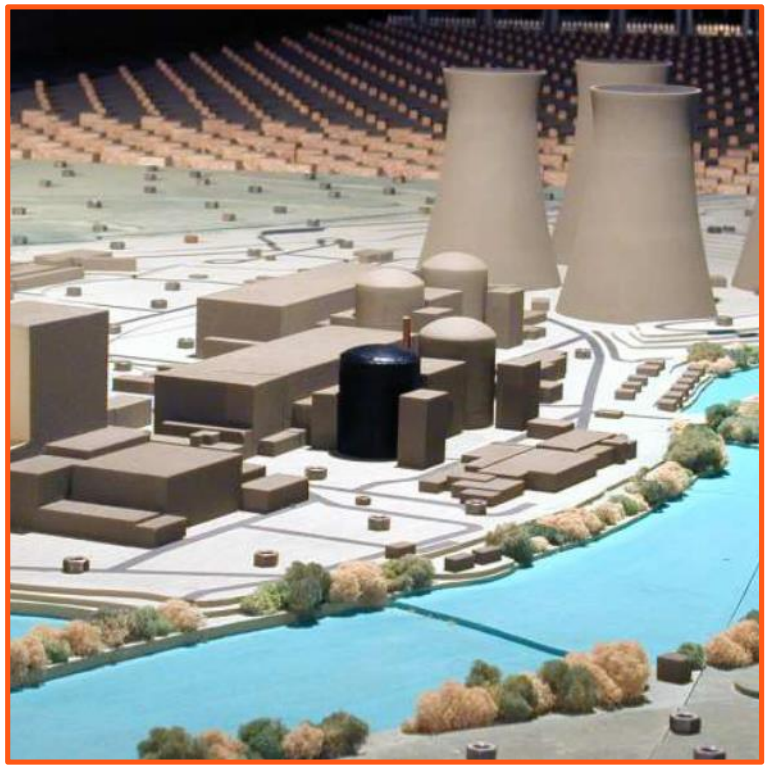
Graphical User Interface of the Safety Atmospheric Lagrangian Model / AST&RISK Atmospheric Simulation of Transport & Risk software

Visualization of the concentration field

Isosurface of concentration

4 - Prospect

- EDF :
  - Wind field databases realization for all nuclear power plants
  - Work in progress with EDF R&D for database realization with EDF tool ➔ Code_Saturne_Atmo
- ECL :
  - Approach applied on different types of industrial sites (urban district, refinery, aluminum industry, …)
  - Inverse modelling in complex terrain to locate and quantify emissions



5 - Conclusion

Collaboration between EDF and ECL :

- Methodology and tools designed to answer the constraints of engineering (time, ability…)
- Qualified tool available for our environmental studies
- Realistic atmospheric modelling taking into account buildings and topography effects


Merci