Application of PMSS, the parallel version of MSS, to the micro-meteorological flow field and deleterious dispersion inside an extended simulation domain covering the whole Paris area

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A few words about models & parallelization

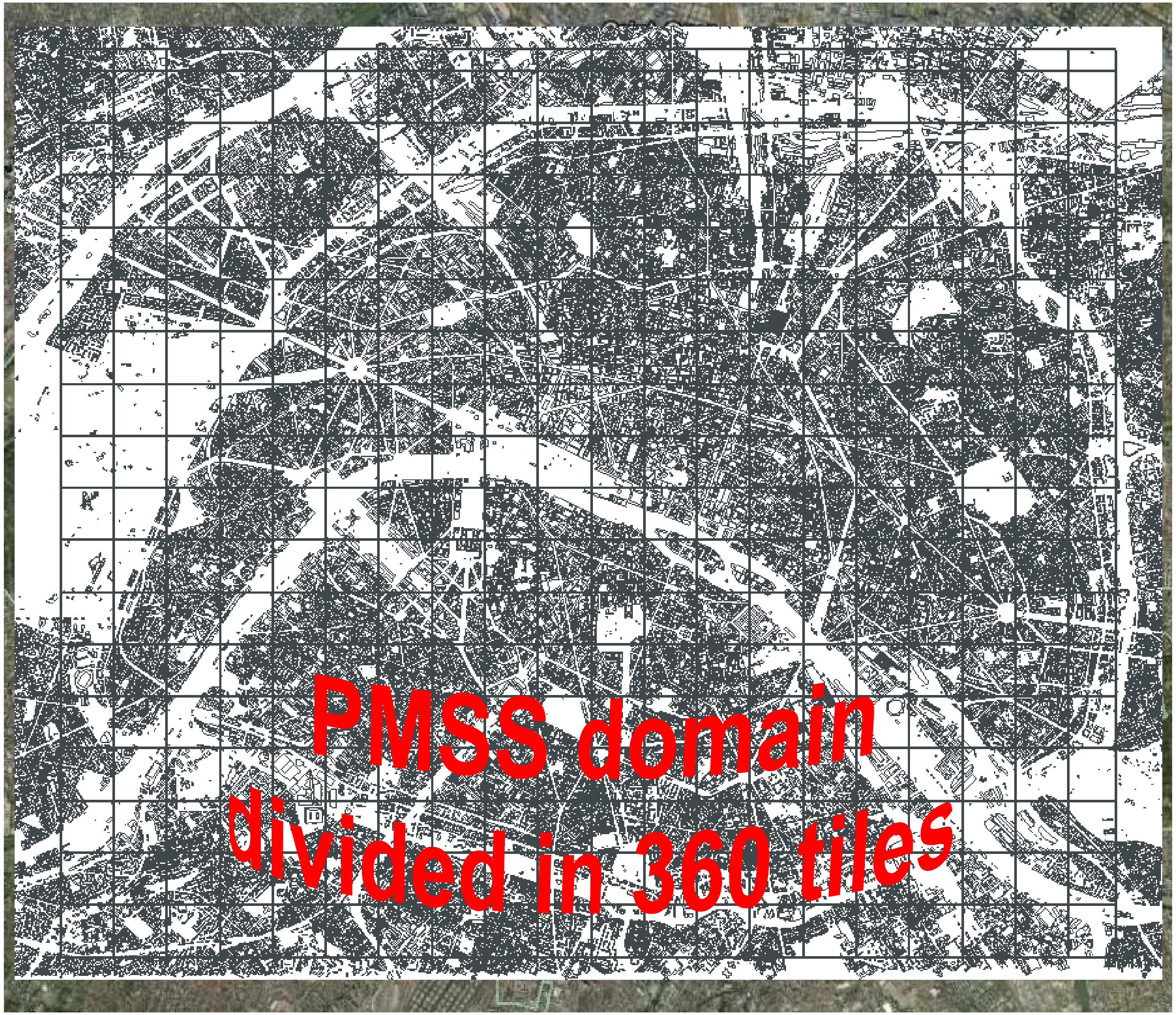
- **Micro-SWIFT-SPRAY (MSS) is designed for meteorological flow & dispersion calculations at local scale taking account of buildings**

- **PMSS is the parallel version of MSS**
  - **µSWIFT & µSPRAY independently parallelized to form a sequential suite**
  - **Parallelization is based on MPI programming system with the objectives**
    - **To reduce computing time**
    - **To deal with "giant'' computation grids (too large for the memory of one core)**

- **PNSWIFT (two modes or combination)**
  1) **Divide out time frames between available cores**
  2) **Split horizontal grid into tiles & allocate each tile to a core**

- **PSPRAY**
  - **Distribution of numerical particles between cores**
  - **Management of active / inactive tiles**
  - **Load-balancing at a user-defined frequency**
  - **Master core defined for each tile**
    ⇒ Compute concentrations & deposition at every synchronization step

The case of ‘‘all Paris’’ – Domain characterictics



- **12 x 10.5 km**
- **3 m mesh resolution**
- **4,001 x 3,501 nodes horizontally**
- **27 nodes vertically between the ground & a height of 1,000 m (logarithmic progression)**

⇩

- **Total amount of ~ 380 millions nodes**

The case of "all Paris" – Input data

- **Topography**
  - Re-interpolation of the IGN 25-meter resolution digital elevation model on the 3-meter resolution horizontal calculation grid

- **Building data**
  - Use of IGN BD-TOPO® building data (shapefile format)
  - 50,000 polygons for the whole Paris area
  - Pre-processor SHAFT converts polygons into ~ 600,000 triangular prisms written under an ASCII format

- **Meteorological data**
  - Results of MM5 calculation in which the finest grid centered on France has a 9-kilometer resolution & 3D wind field is computed every hour
  - Pre-processor MM5-to-ARIA extracts vertices for wind, temperature & absolute humidity on a 12-hour long period (from 09/21/2010 at 19:00)

The case of "**all Paris**" – Computing resources

– **Calculations are done with High Peformance Computing resources of the CEA / Research & Technology Computing Center (CCRT)**
http://www-hpc.cea.fr/en/complexe/ccrt.htm

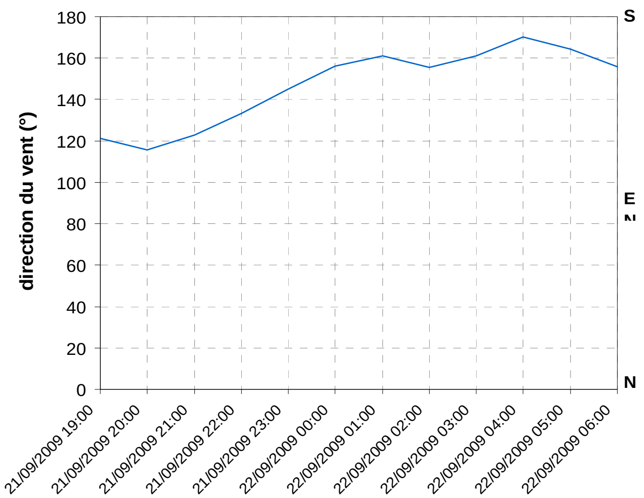
– **47.7 Tflops BULL Itanium cluster with 932 nodes of 8 cores**
$\Rightarrow$ **More than 7,000 1.6 GHz Itanium cores**

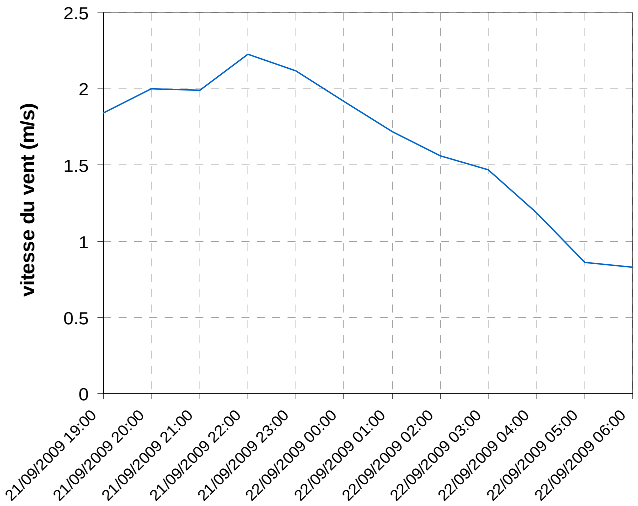
– **SWIFT $\rightarrow$ Domain splitted in 360 tiles & calculation uses 361 cores**

– **SPRAY $\rightarrow$ Two test-cases with the same 3D wind field**
  - **Case A : 20 min. release of a gaseous chemical substance from "place de l'Etoile" (near Arc de Triomphe)**
  - **Case B : 2 min. release of a radioactive aerosol near "parc des Buttes Chaumont" (in the North-East)**

The case of “all Paris” – Case A meteorological data

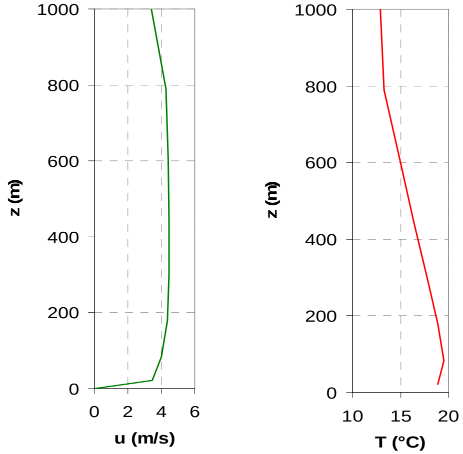
Extraction near “place de l’Etoile” of ground data (chronology) & vertical profiles (at different times)



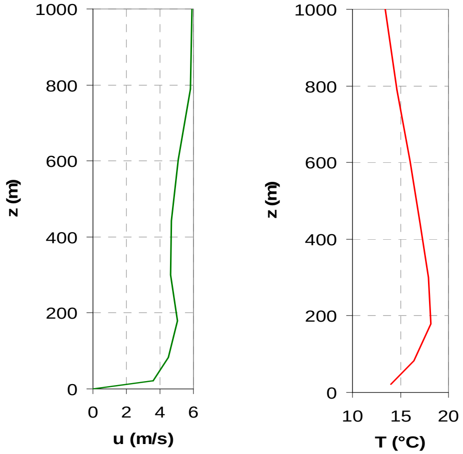


Wind above the urban canopy blows from South-East at the beginning of the period & turns gradually to South as its velocity decreases

21/09/2009 19h00



22/09/2009 00h00



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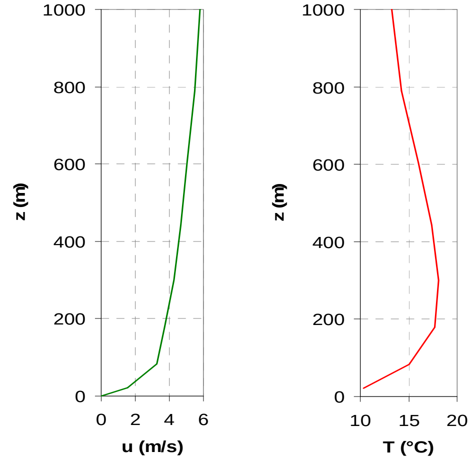


The case of "all Paris" – Case A dispersion results

ZOOM

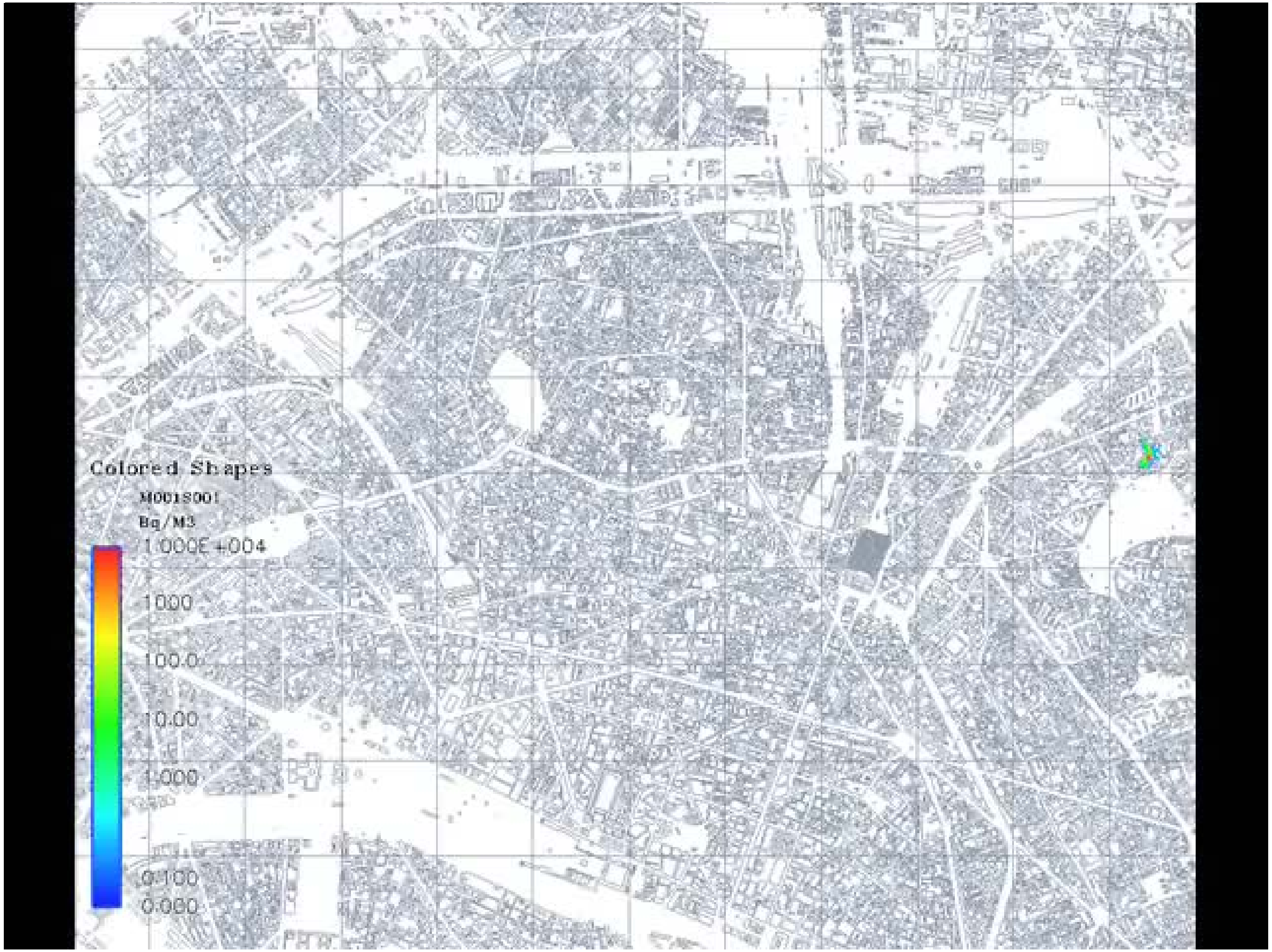
Atmospheric concentration near the ground (0 - 3 m) computed every minute

Simulated period lasts two hours (release in the first 20 min. of 21,600,000 particles)

The case of "all Paris" – Case B dispersion results

ZOOM

Atmospheric concentration
near the ground (0 - 3 m)
computed every minute

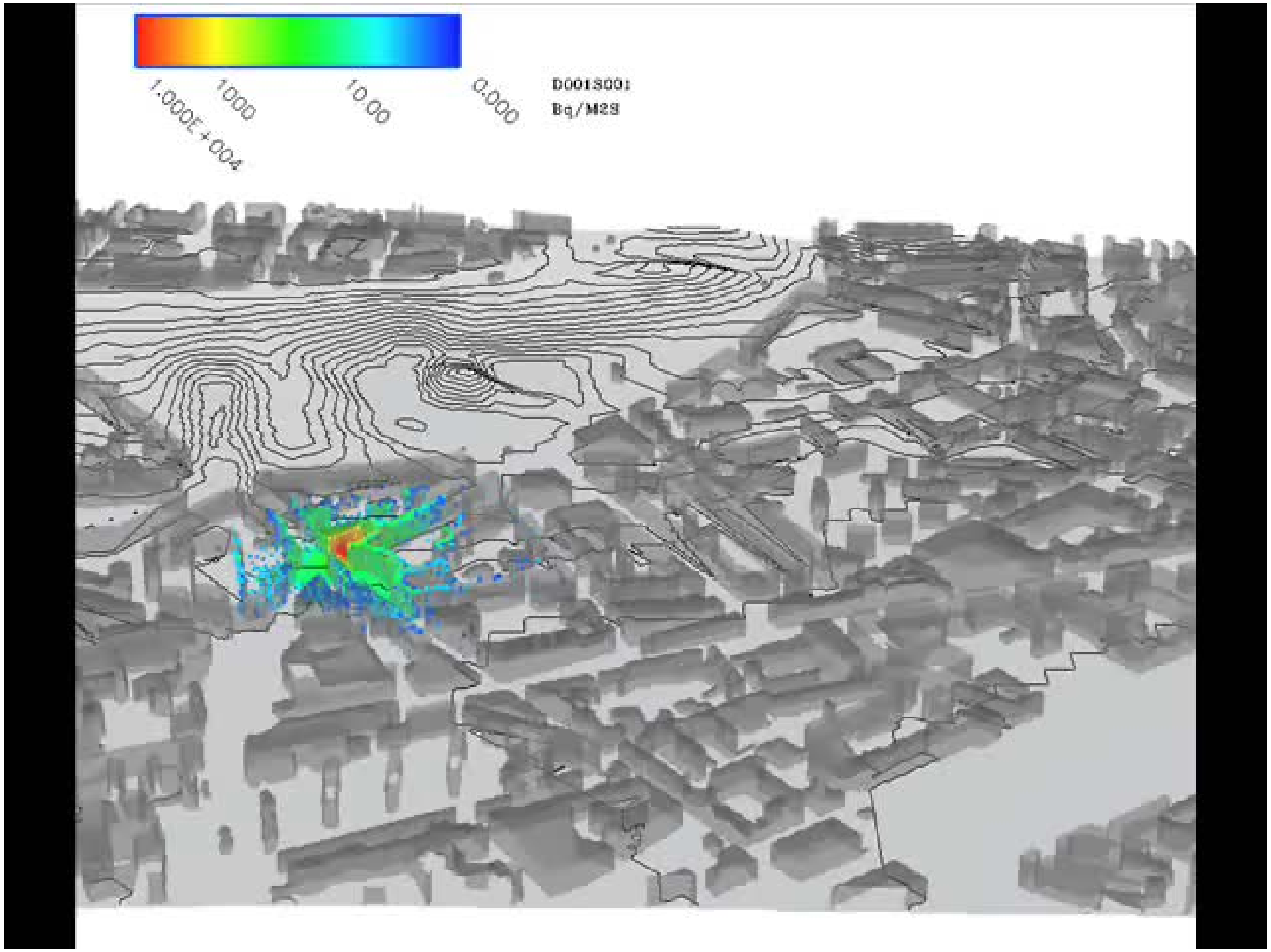


Simulated period lasts two hours (release in the first 2 min. of 10,800,000 particles)

The case of "all Paris" – Case B dispersion results

ZOOM

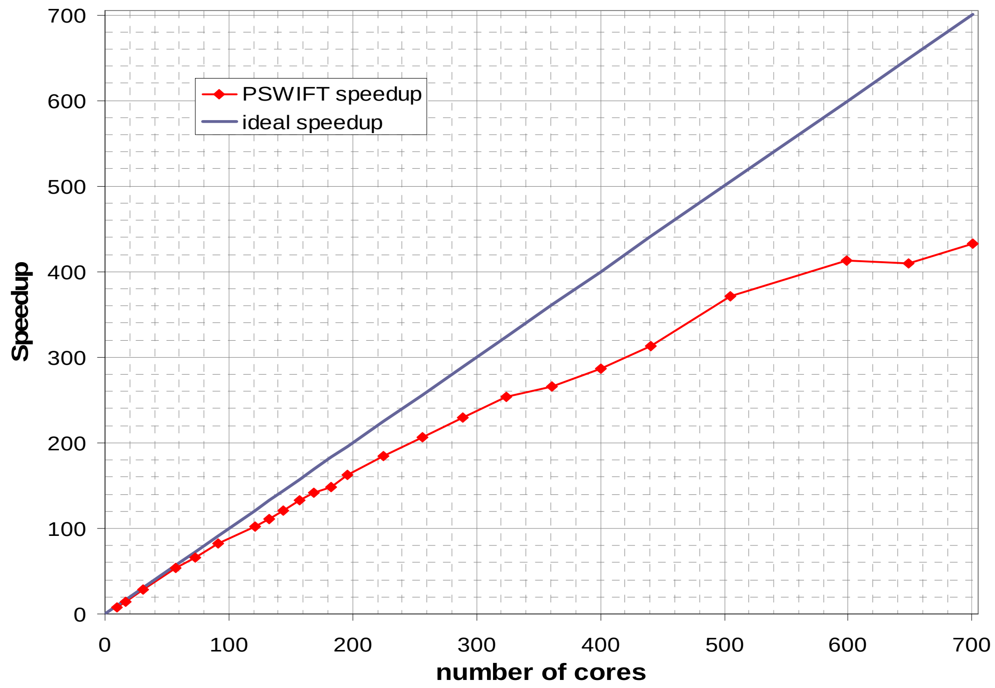
Deposition on ground, walls & roofs, recorded every minutes



Simulated period lasts two hours (release in the first 2 min. of 10,800,000 particles)

Parallel-SWIFT performances

- Calculations for a various number of cores to evaluate speedup $S_n = T_1 / T_n$ where T_n is the execution time for n cores
- PSWIFT speedup is close to ideal for $n_{cores} < 100$, very good with some hundreds of cores & continues to grow for $n_{cores} \sim 700$



Results for 12 time frames (12 hours)

n_{cores}	Execution time
121	2 hours
256	1 hour
599	0.5 hour

PSWIFT parallelization is very efficient (few com. between cores)

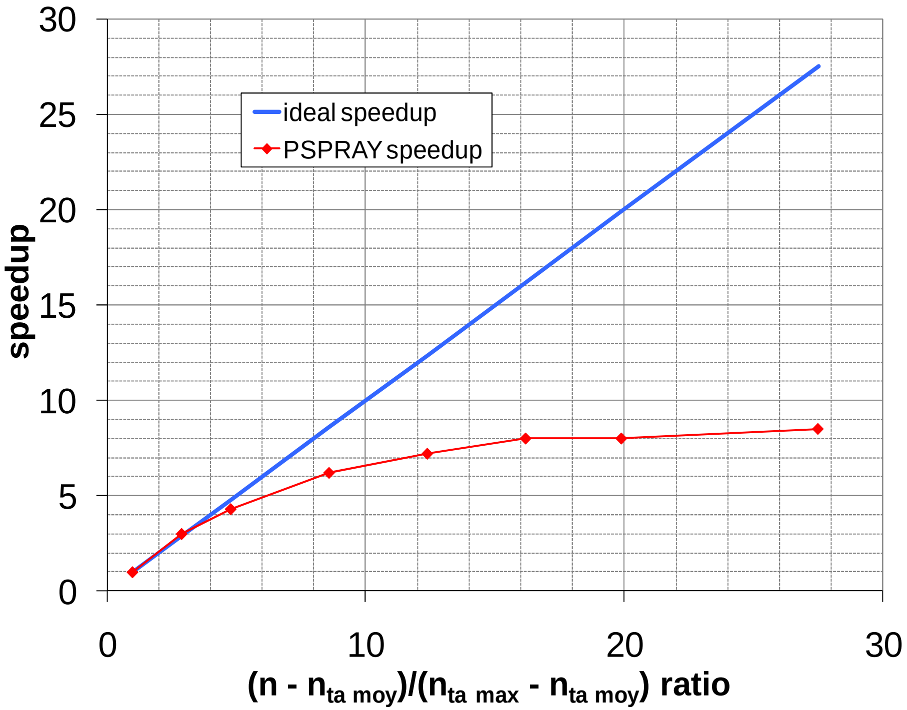
n_{cores}	31	57	91	121	169	225	361	599
Speedup	28	54	82	102	141	184	266	413

Parallel-SPRAY performances

- Performances of PSPRAY are assessed in relation to test-case A
- In this case, 48 tiles at most are active at the same time

  ⇒ Calculations are performed with 49 cores or more
- Speedup is defined with $n_{ta\ max} = N_{ta\ max} + 1$ and $n_{ta\ moy} = N_{ta\ moy} + 1$ where $N_{ta\ max}$ is the max. Nr and $N_{ta\ moy}$ the average Nr of active tiles in the calculation

$$S\left(\frac{n - n_{ta\ moy}}{n_{ta\ max} - n_{ta\ moy}}\right) = \frac{T_{n_{ta\ max}}}{T_n}$$



- PSPRAY speedup depends on release scenario & input options (tiles size, load-balancing...)
- In this case, speedup is close to ideal for $n_{cores} < 150$
- PSPRAY speedup doesn't increase for $n_{cores} > 250$ as there are too many communications bet. cores
- For $n_{cores} = 150$, the calculation duration is ~2h due to the huge amount of numerical particles (21.6 M)
- When the number of released particles goes down, the execution time significantly decreases

General conclusions

- **PMSS allows to compute atmospheric dispersion on huge urban domains**
- **Calculated concentrations are very precise & relevant inside each street**
- **Depositions on ground, walls & roofs have the same precision**
- **Health impact can be assessed as post-processing**

- **PSWIFT parallelization very efficient due to few communications between cores**
- **PSPRAY evaluation of speedup is more difficult as it depends on input data**
- **PSPRAY speedup is quite good except for high numbers of cores**
  ⇒ Optimization of MPI procedures should improve calculation time & efficiency

- **Promising performances for PMSS future operational use on extended built areas**
- **Automatic PNSWIFT forecast at the micro-scale from meso-scale weather forecast (e.g. 12-hour forecast on all Paris obtained in ~1.5 hour using a 128-core cluster)**
- **Then, PSPRAY can be activated on demand, in case of an emergency, to compute dispersion & health impact in a short time (less than ten minutes)**