Development of a 3D modelling suite from the global scale to the urban scale using MM5 and Micro-SWIFT-SPRAY. Application to the dispersion of a toxic release in New York City

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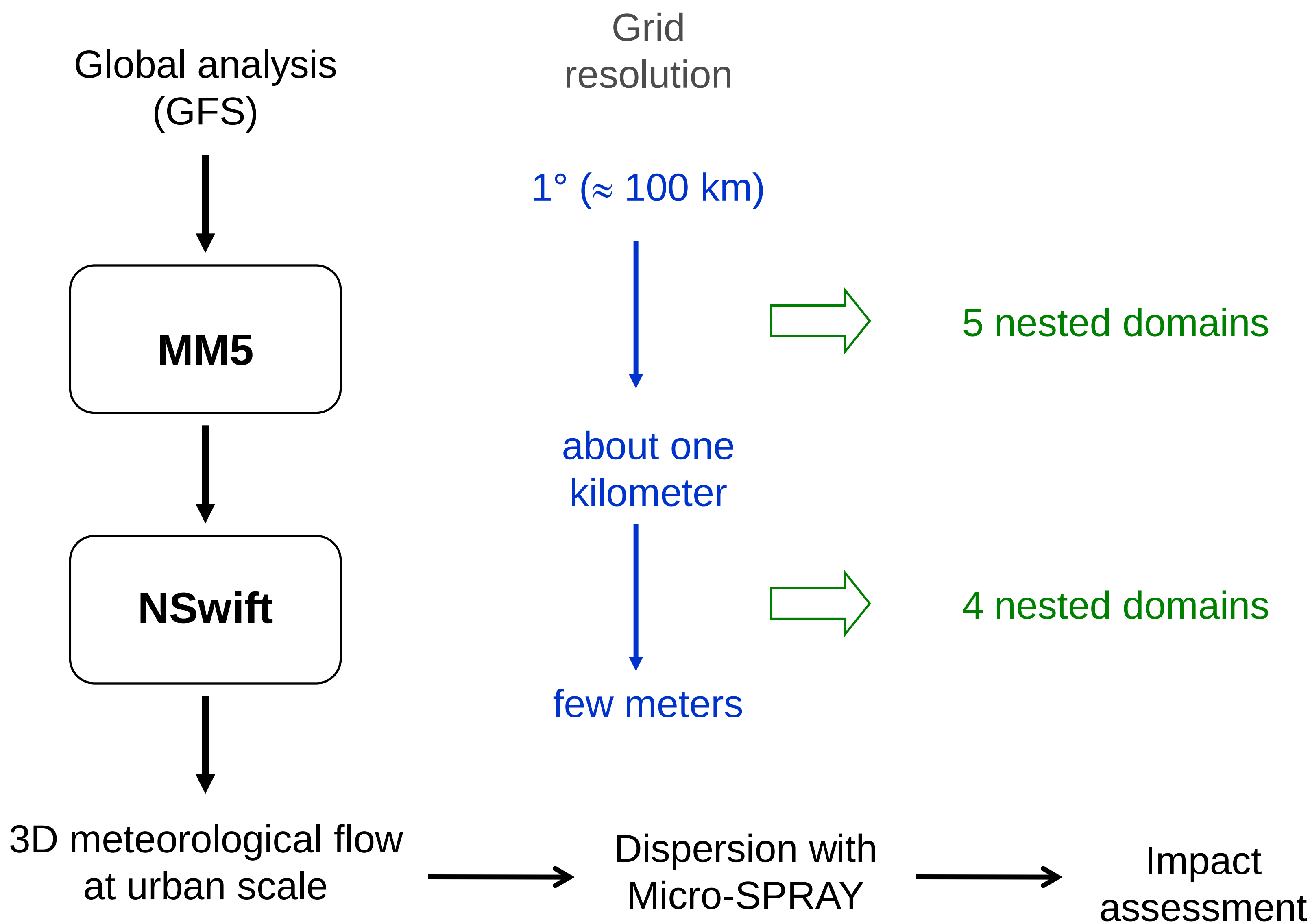
Downscaling



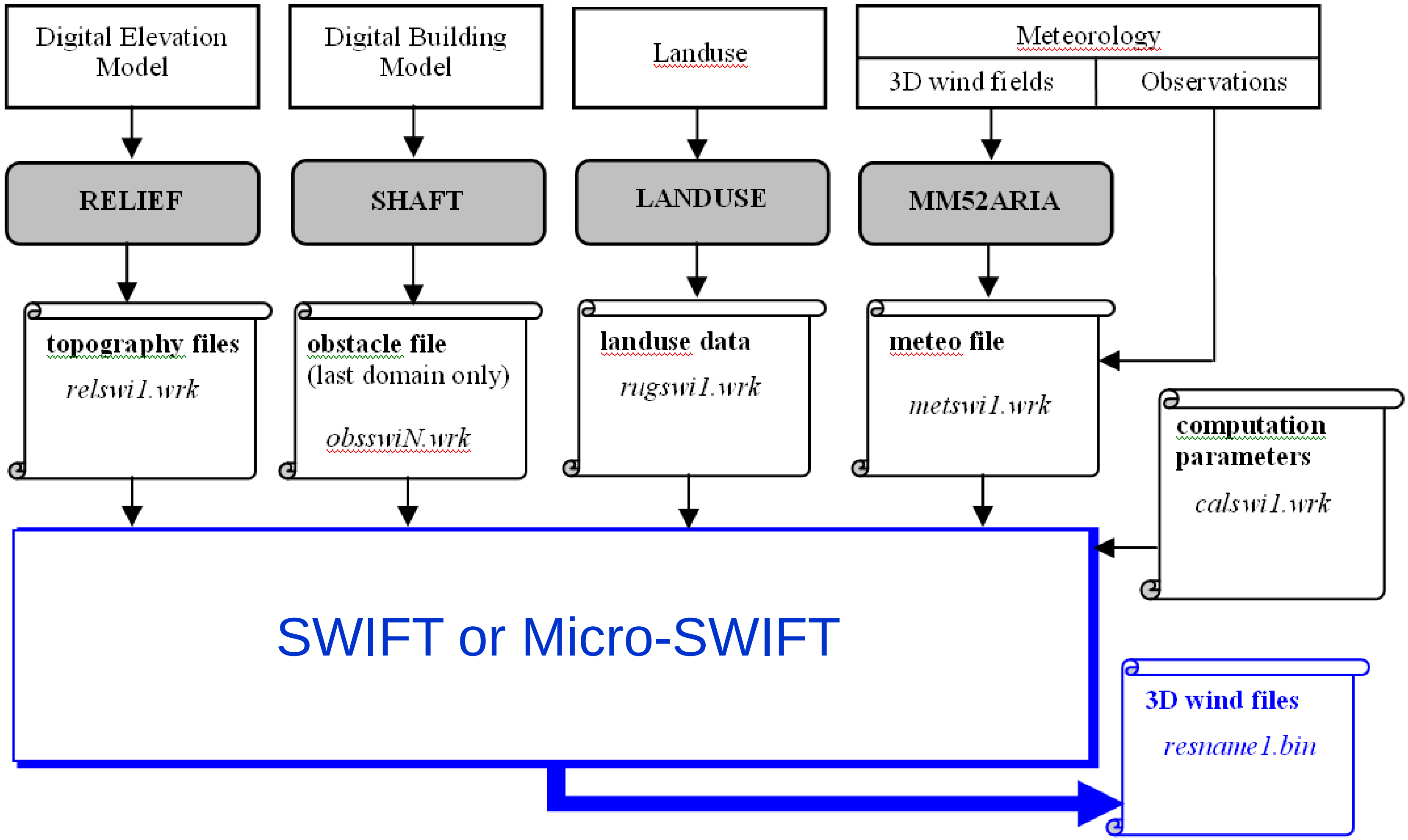
A few words about models …

- **MM5**
  - A parallelized, limited area, nonhydrostatic, terrain following and sigma-coordinate model designed to simulate or predict mesoscale atmospheric circulation (Dudhia, J. *et al*., 2005)
  - ⊕ works in two-way nesting.
  - ⊕ some phenomena like convection are explicitly solved.

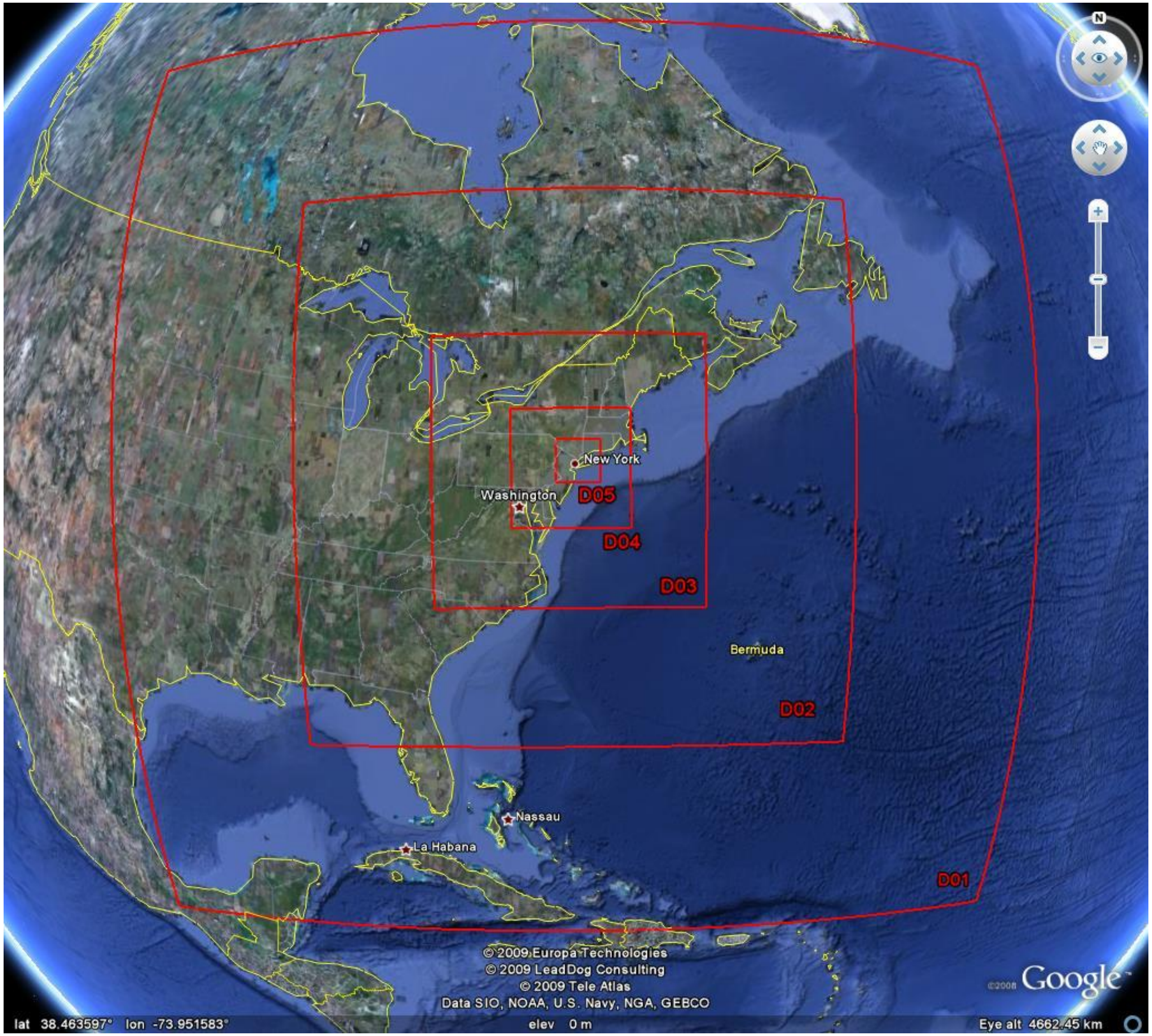
- **NSwift**
  - Diagnostic meteorological model, developped and maintained by ARIA Technologies and ARIANET, based on mathematical interpolation (for wind, temperature and humidity). Then, adjustment to produce a mass consistancy wind field (no conservation of energy and momentum).
  - ⊕ works in one-way nesting at this time.
  - ⊕ a better description of topography and landuse allows to refine mesoscale 3D fields.
  - △ Choice of simulation parameters may lead to lose informations about turbulence.

Architecture of NSWIFT

✓ NSWIFT only manages successive calls to SWIFT or Micro-SWIFT via a xml command file



Domains characteristics



MM5

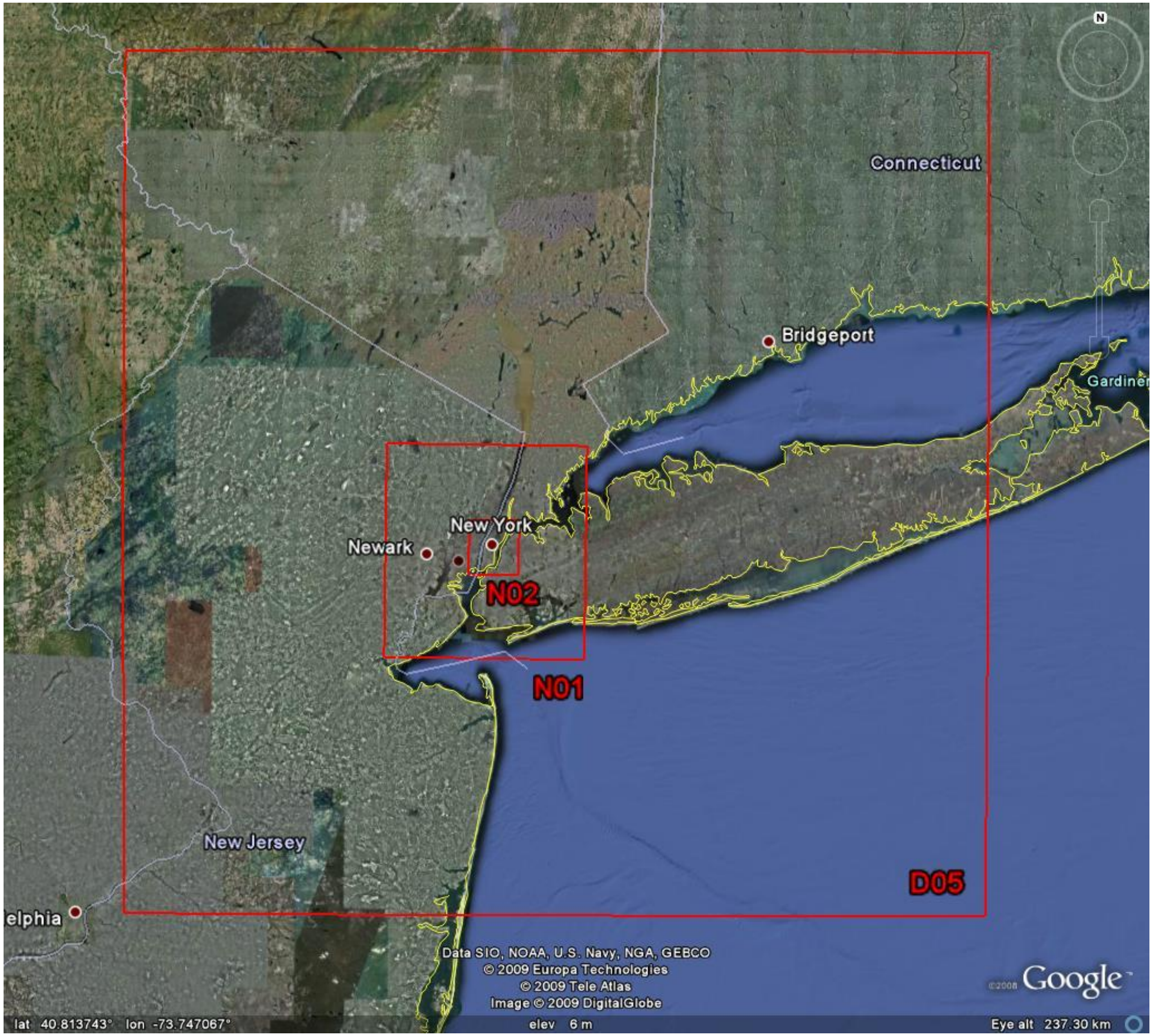
D01 60×60 nodes
mesh = 81 km

D02 100×100 nodes
mesh = 27 km

D03 142×142 nodes
mesh = 9 km

D04 184×184 nodes
mesh = 3 km

Domains characteristics



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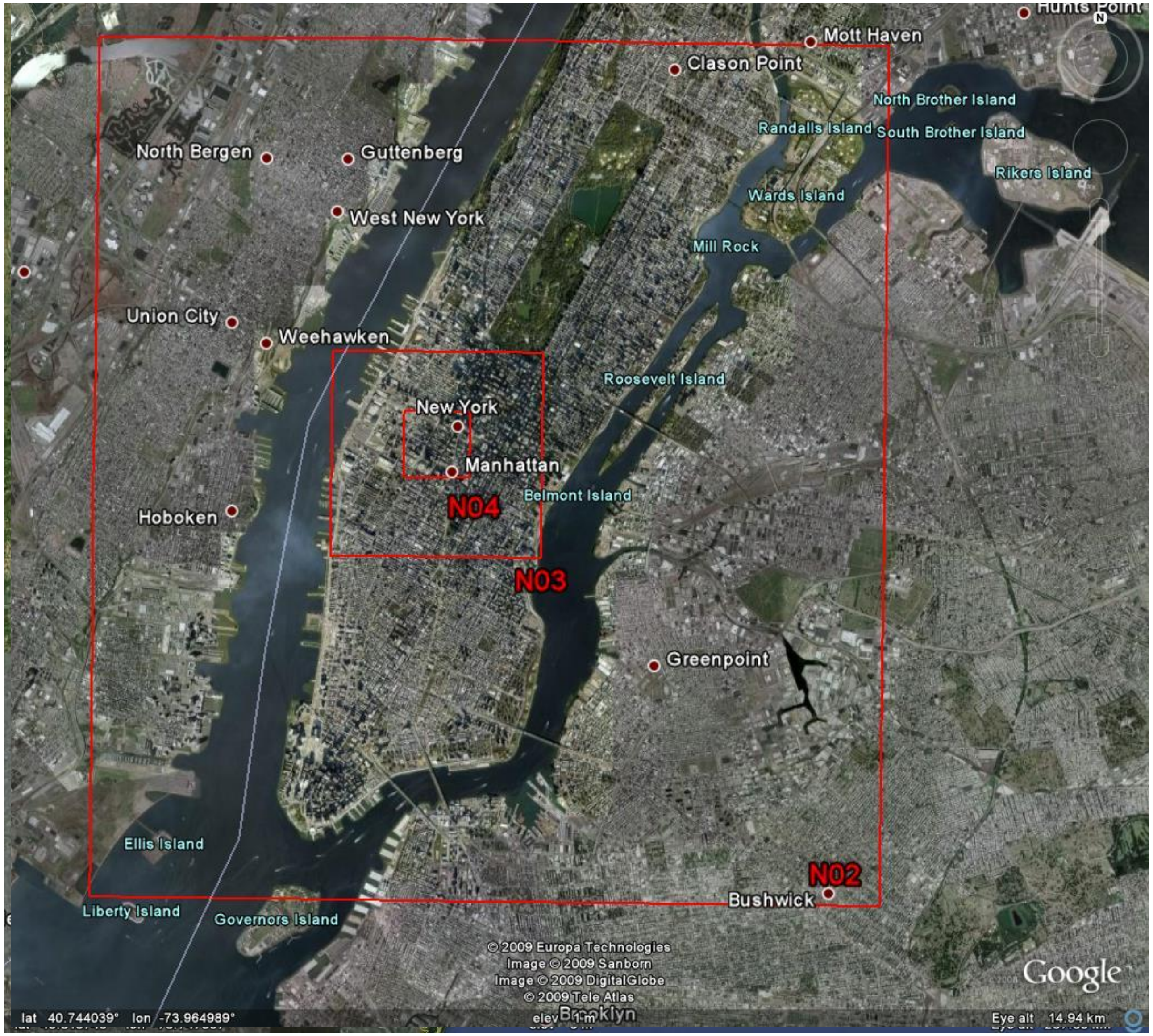
D05 202×202 nodes
mesh = 1 km

NSwift

N01 161×171 nodes
mesh = 300 m

Domains characteristics



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D05 202×202 nodes
mesh = 1 km

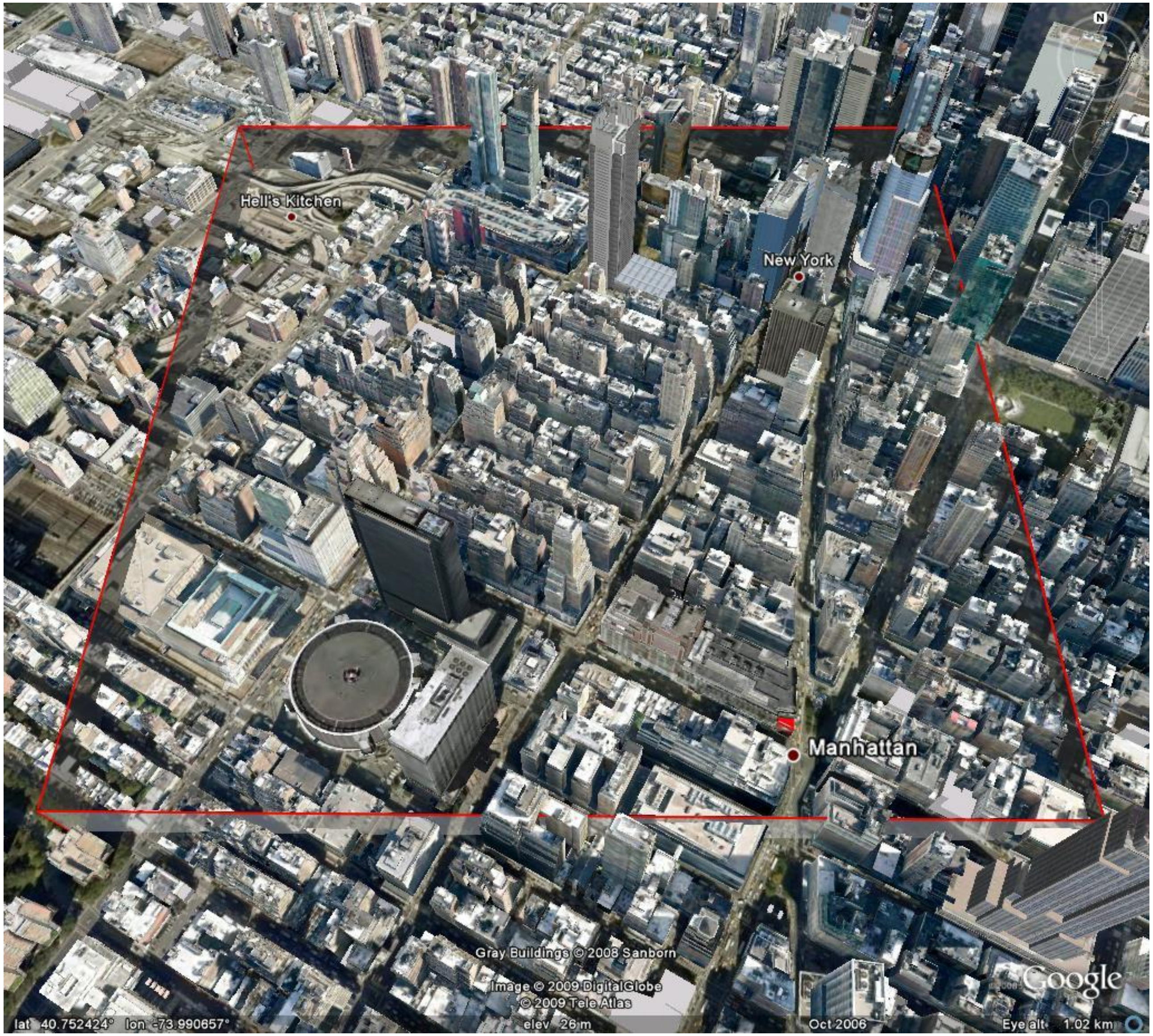
NSwift

N01 161×171 nodes
mesh = 300 m

N02 121×131 nodes
mesh = 100 m

N03 161×156 nodes
mesh = 20 m

Domains characteristics



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D05 202×202 nodes
mesh = 1 km

NSwift

N01 161×171 nodes
mesh = 300 m

N02 121×131 nodes
mesh = 100 m

N03 161×156 nodes
mesh = 20 m

N04 251×251 nodes
mesh = 4 m

Spatial resolution and source of topography and *landuse* data

Domain	Mesh size	Data resolution	Topography	Landuse
D01	81 km	30 min. (~55 km)	DEM_30M_GLOBAL	VEG-USGS.30
D02	27 km	10 min. (~18,5 km)	DEM_10M_GLOBAL	VEG-USGS.10
D03	9 km	2 min. (~3,7 km)	DEM_02M_GLOBAL	VEG-USGS.02
D04	3 km	30 sec. (~0,925 km)	GTOPO30	VEG-USGS.30s
D05	1 km	30 sec. (~0,925 km)	GTOPO30	VEG-USGS.30s
N01	300 m	3 sec. (~90 m)	USGS 1:250000 Scale DEM	USGS (US EPA .shp format) + projection on target grid
N02	100 m			
N03	20 m	10 m	NYS DEC 1:24000 DEM	
N04	4 m			Uniform

GLOBAL DATA

LOCAL DATA

3D building model is introduced instead of taking into account buildings through a landuse class

Refining roughness 3D field

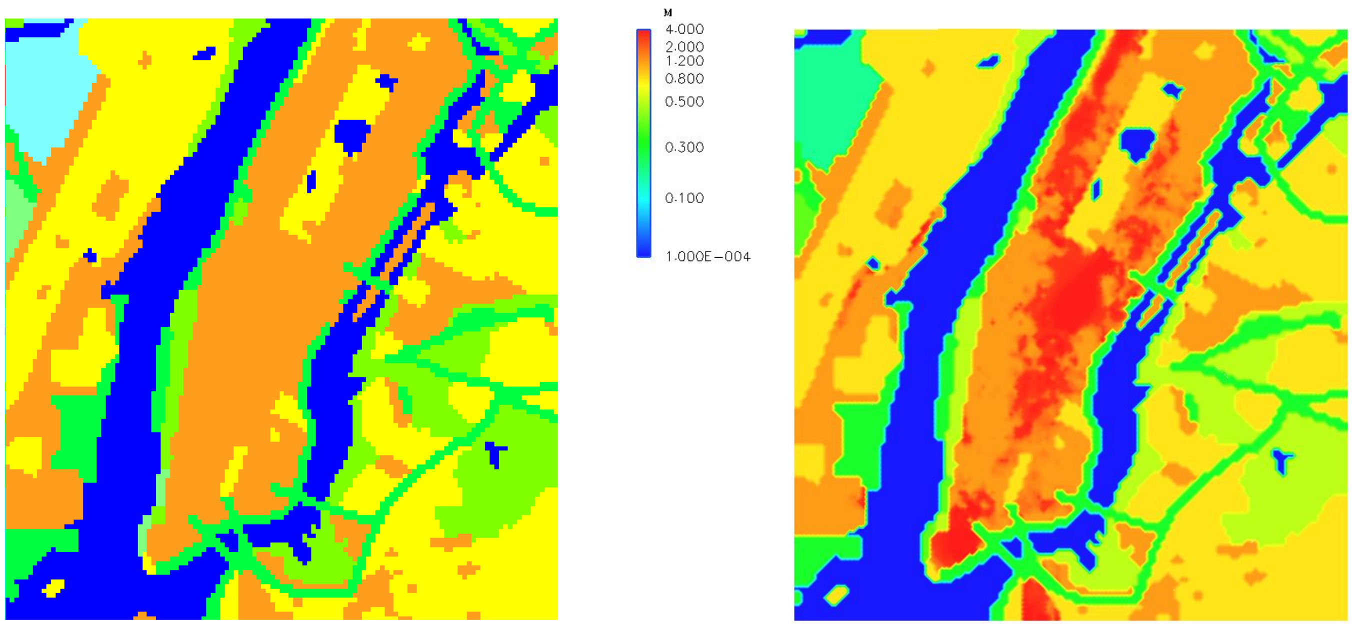
Domain N01 : landuse classes are associated to tabulated data to attribute a value to roughness length, albedo and Bowen ratio

Domain N02 : on Manhattan island, a single landuse class (except Central Park)

→ use of morphometric methods (Grimmond,1999) to determine roughness

$z_0 = f_0 \cdot \bar{z}_H$ where z_H is the height difference between a DEM and a DSM

$$z_0 = \max\left(f_{0\,tabulated};\ f_0 \cdot \bar{z}_H\right)$$

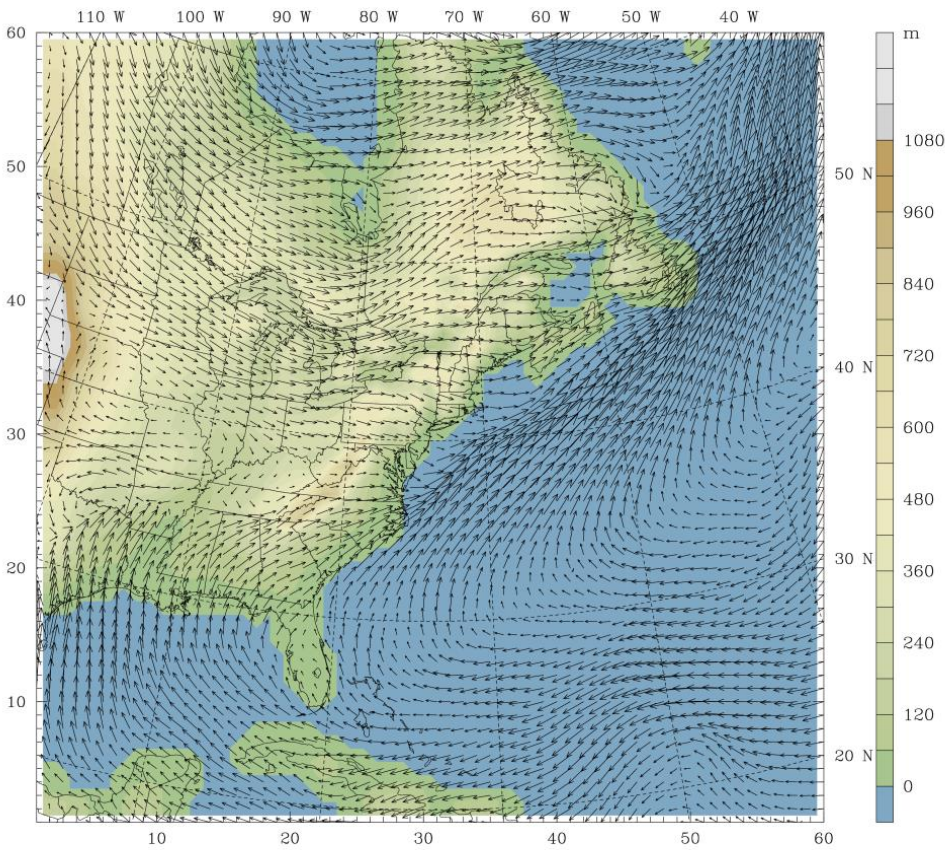


Meteorological flow results

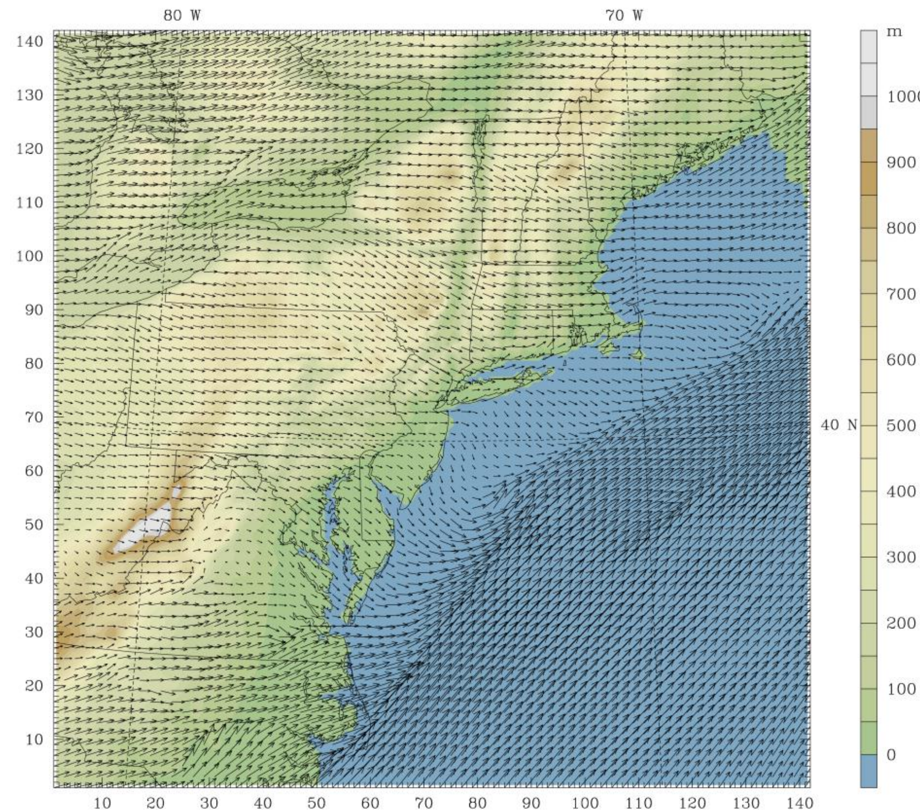
MM5 results

Simulation on 5 days (from April 29, 2009 to May, 2nd 2009) with every-15-minutes records → 480 3D fields

D01



D03



Comparison with observations

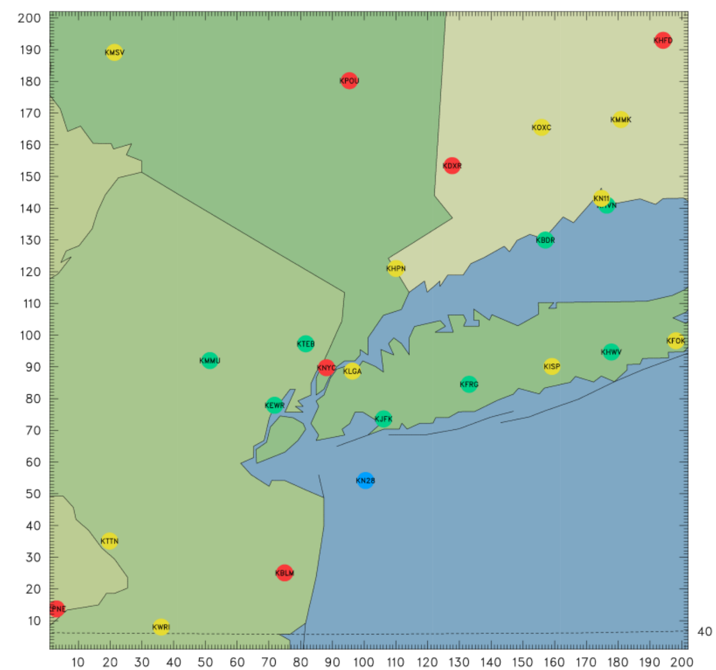
MM5 wind fields are compared with observations of the METAR network

An objective criterion is performed for each surface station of the METAR network inside domain D05, which compares observed wind roses to calculated wind roses for these locations (Soulan, 2004)

$$C_{global} = 100 - \frac{1}{2}\left(\sum_{i=1,18\times 4} \left| g_i^{METAR} - g_i^{MM5} \right| \right)$$

where C_{global} is the value for the criterion in percentage and g_i the occurrence for class i of simulated (MM5) or observed (METAR) wind rose.

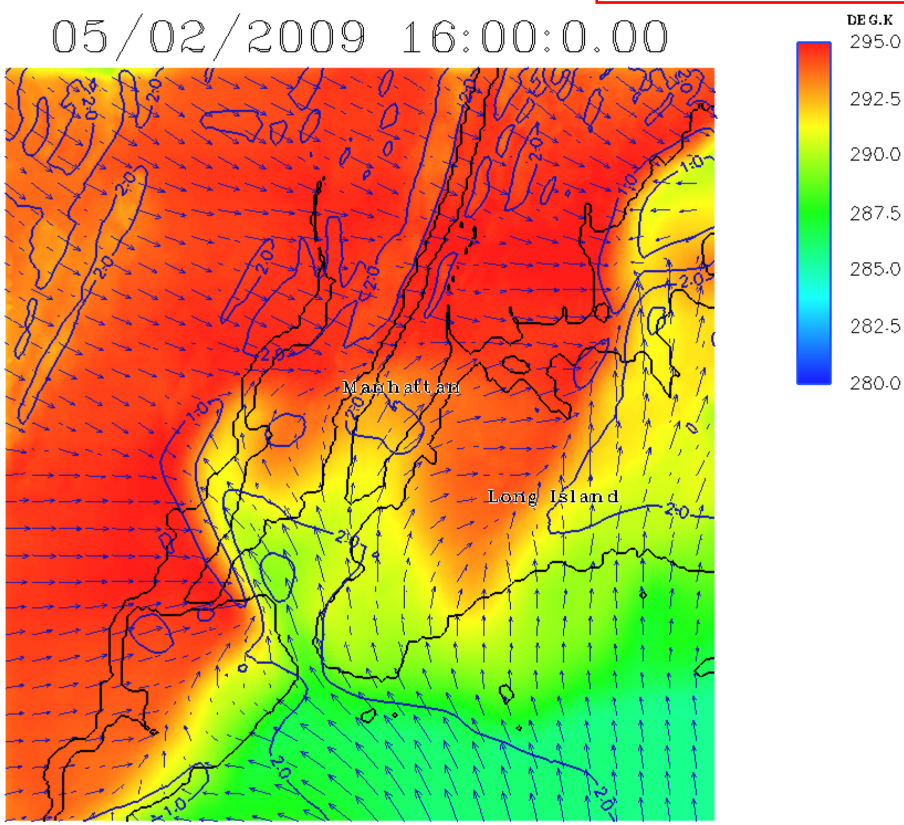
	D01	D02	D03	D04	D05
Average on the 25 METAR stations included inside D05 (%)	43,7	49,9	53,0	53,9	53,5

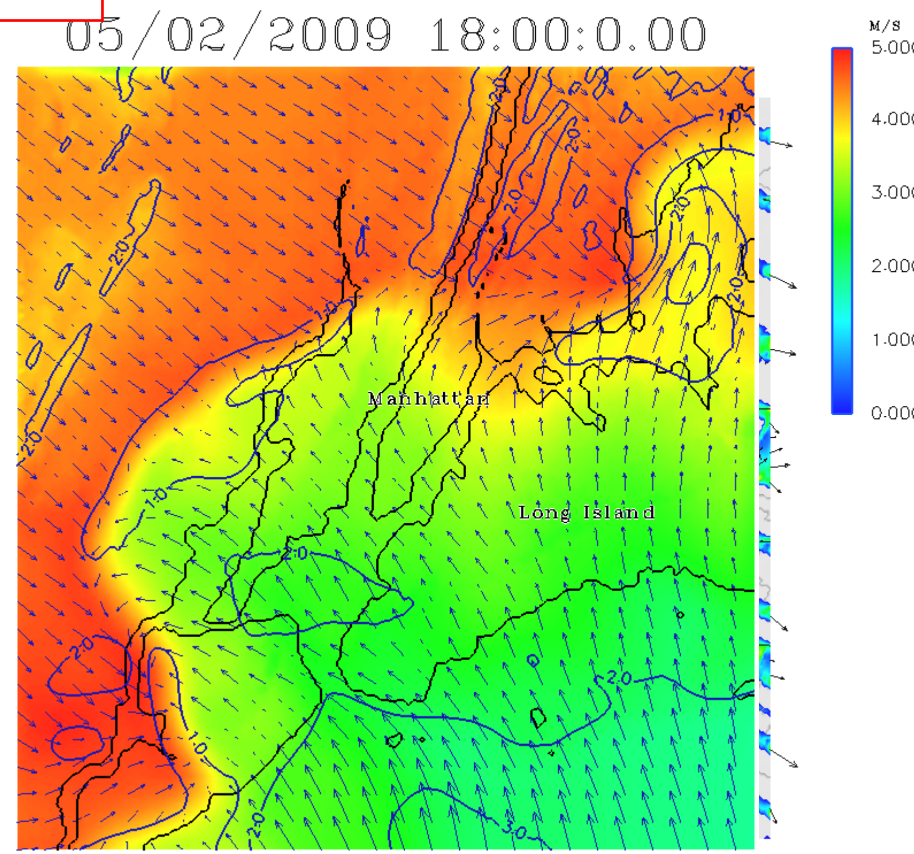


NSWIFT results

Simulation on 2 hours (between 16:00 and 18:00 on May, 2nd 2009) with every-15-minutes records → 9 3D fields

N01 **Sea-breeze effect** **N04**



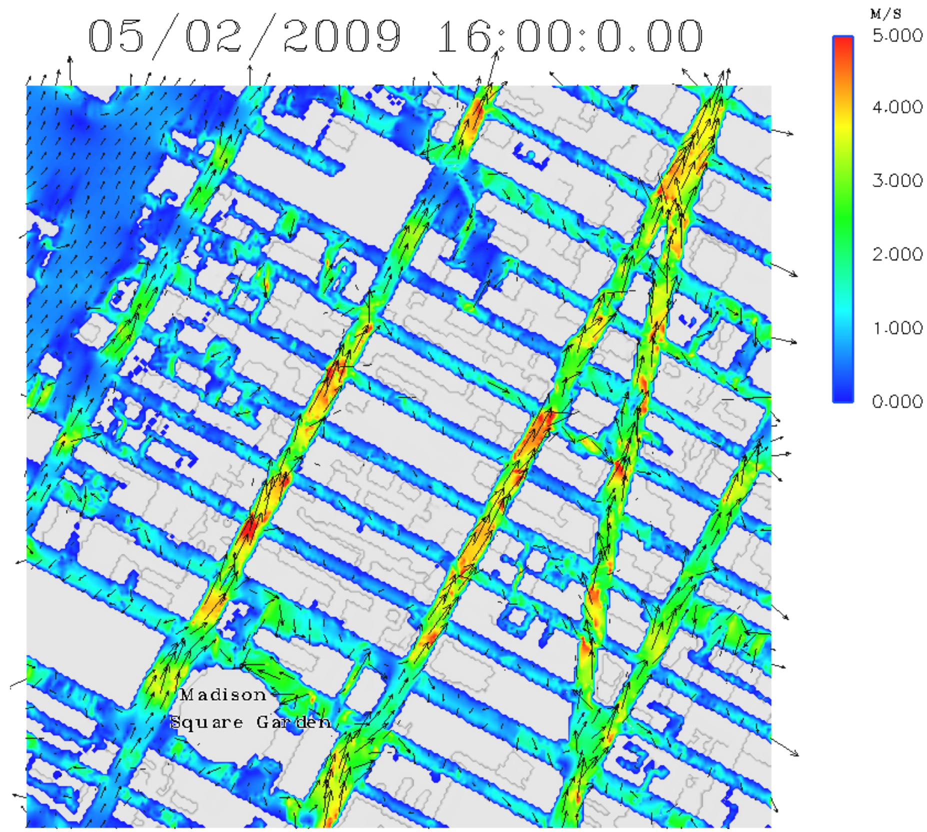


NSWIFT results

Simulation on 2 hours (between 16:00 and 18:00 on May, 2nd 2009) with every-15-minutes records → 9 3D fields

N04

Increase of wind speed inside street canyon

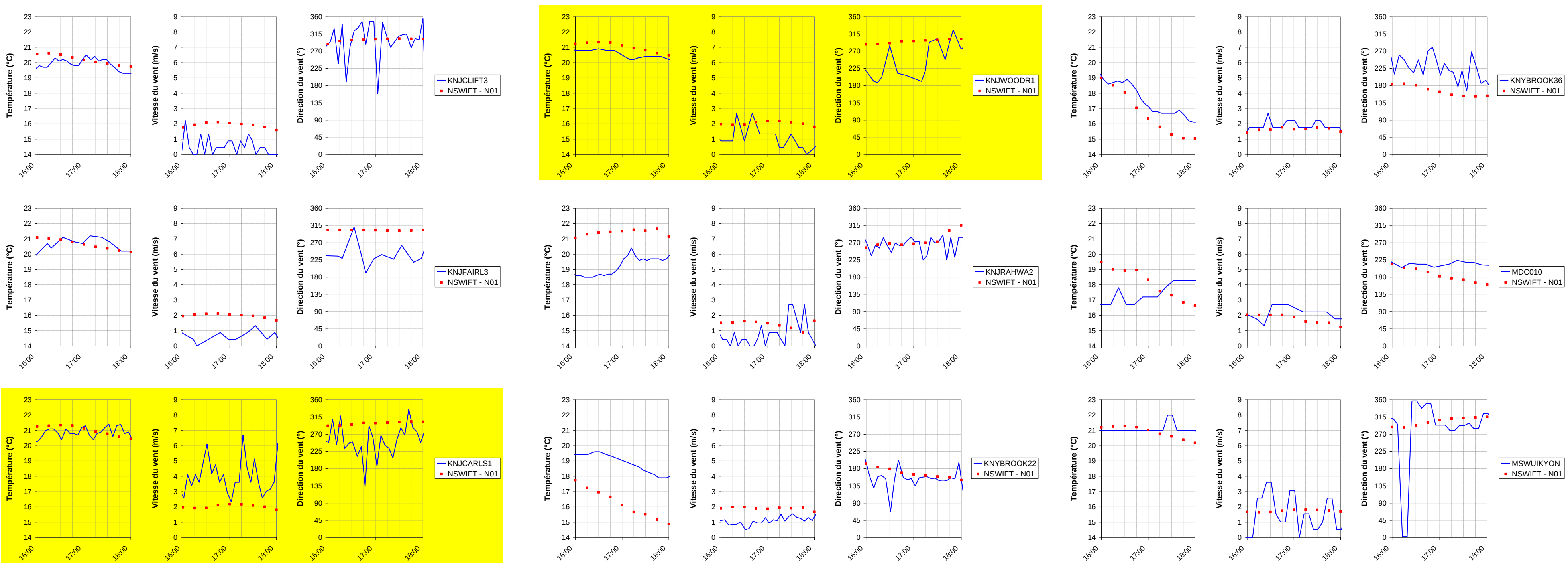


Comparison with observations

Few METAR stations inside NSWIFT domains

Website http://wunderground.com/weatherstation/index.asp provides meteorological surface observations. Dozens of local stations inside NSWIFT domains.

But many of them are not representative of local meteorology or don't provide data for the simulated period.



Dispersion with Micro-SPRAY

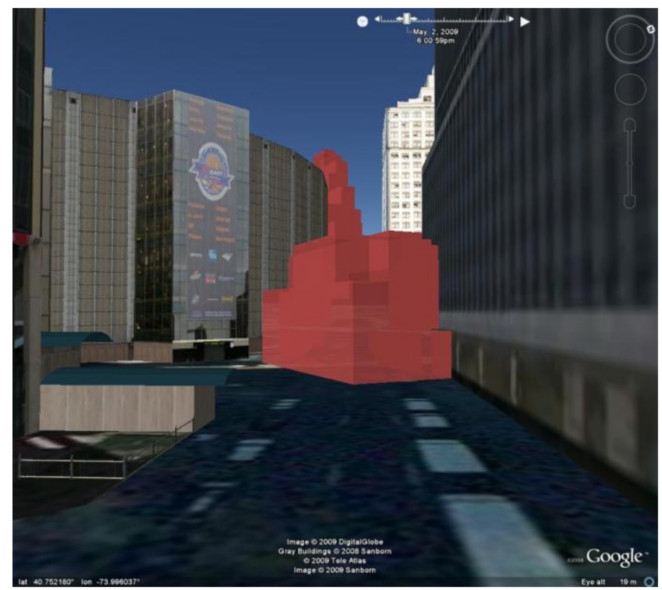
An hypothetical toxic release, which could be due to a terrorist attack, is assumed to take place in front of one of Madison Square Garden's gate.

Dispersion is computed on the finest grid (N04) using Micro-SPRAY.

Release, due to an explosion, is assumed to be a small cloud with a stem and a cap.

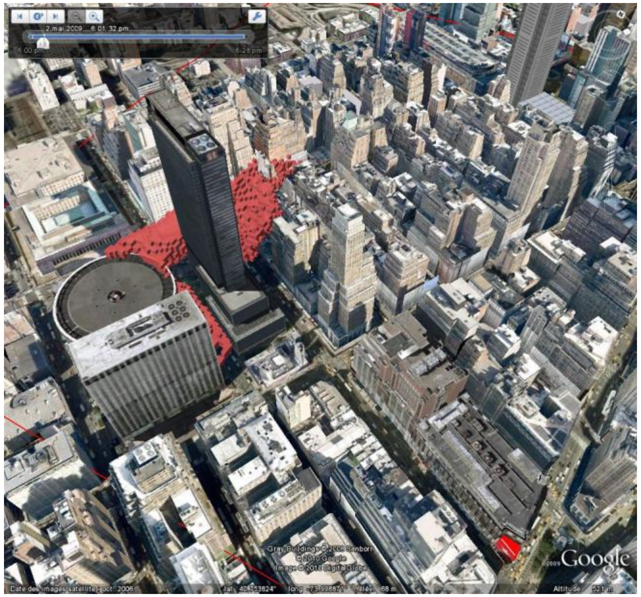
The Micro-SPRAY simulation is performed for a period of two hours, with a concentration field computed every minute.

A total amount of $2{,}4.10^6$ numerical particles has been emitted to represent dispersion of the cloud.

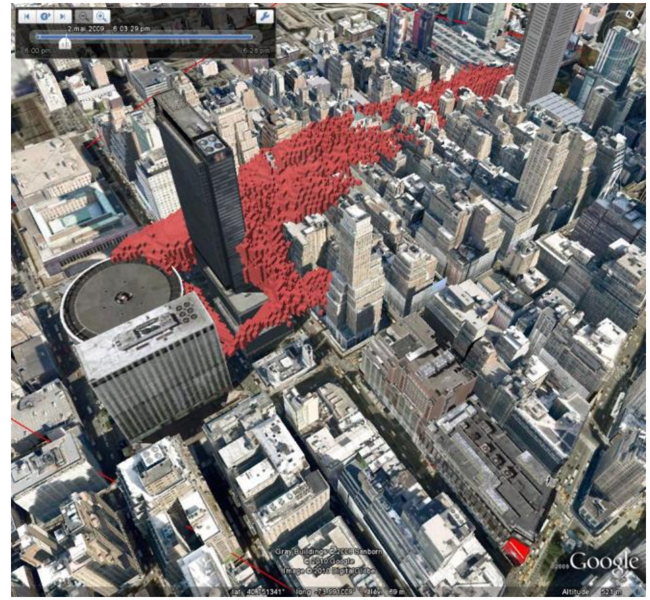


Dispersion with Micro-SPRAY

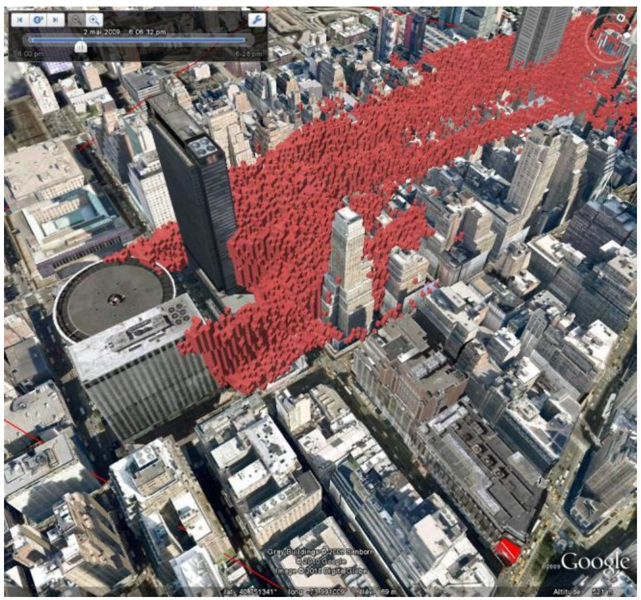
T0+2min



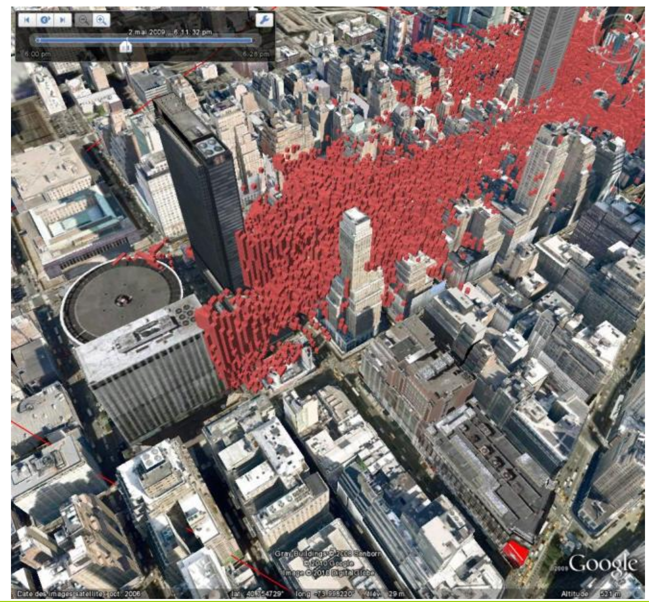
T0+4min



T0+7min



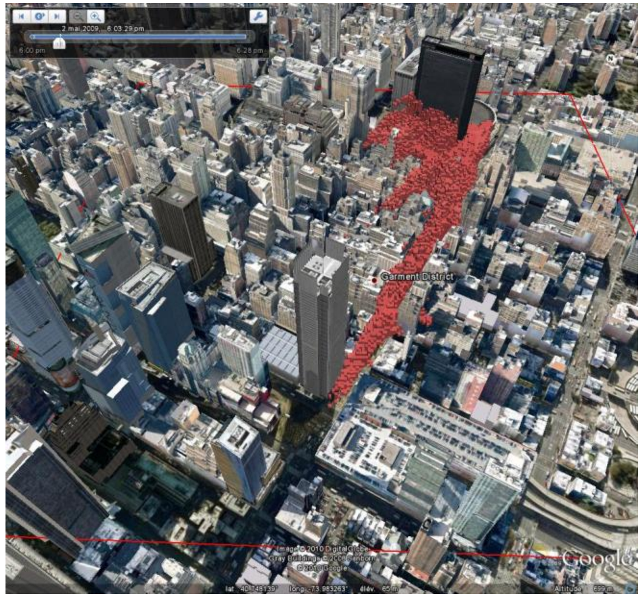
T0+12min



Dispersion with Micro-SPRAY

T0+2min

T0+4min



T0+7min

T0+12min

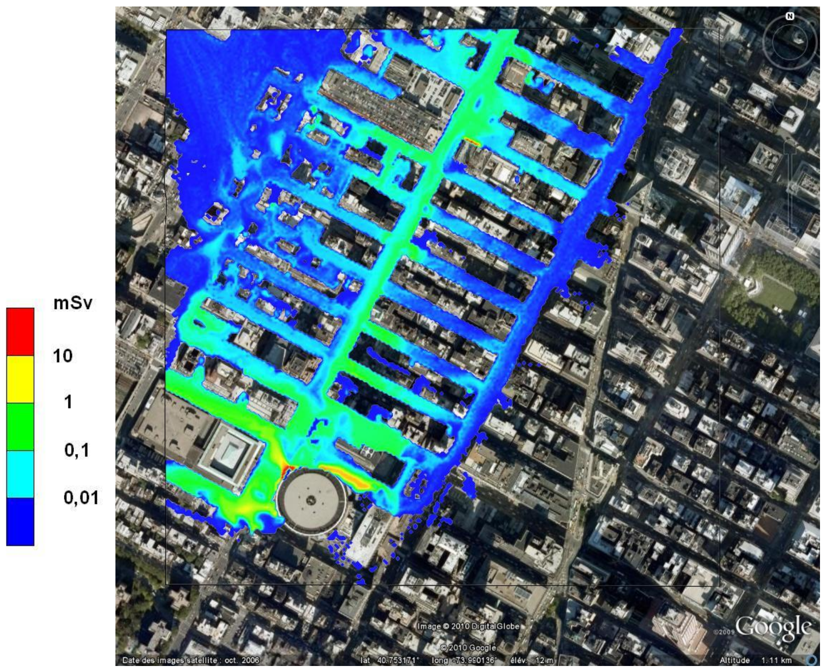
Impact assessment

From dispersion results, post-processing allows to compute chemical doses or radiological exposures, depending on the nature of emitted species.

If we assume that release is radioactive Cobalt-60, we are able to compute short-term radiological impact, like inhalation dose or radiation exposure.

In each point (I,J) of the grid, inhalation dose for a not moving person verifies :

$$H_{inh}(I,J) = \left(\sum_{t_i=t_1}^{t_i=t_N} C(I,J,K=1,t_i) \cdot \Delta t \right) \cdot \frac{\tau_{resp}}{3600} \cdot f_{inh} \cdot 1000$$



Radiation exposure is quite more difficult to perform because it has an effect from a distance.

A tool like CLOUDSHINE (Armand, 2005) performs dose field due to gamma radiations emitted by a cloud.

At this time, no tool to perform radiation exposure due to ground deposition.

Conclusion and perspectives

- the MM5-NSWIFT-Micro-SPRAY suite is able to compute meteorological flows from global scale to the urban local scale in one run, and then calculate dispersion and health impact.
- Local observations are not necessary any more to perform wind fields at the local scale, but are still able to be added to 3D input meteorological fields.
- The main interest in the MM5-NSWIFT-Micro-SPRAY suite is to offer a complete and very relevant answer in case of dispersion of a dangerous specie inside urban environment.
- Introducing obstacles at local scale could be improved because buildings description turns from a parameterization through roughness to an explicit description.
  A development, who consider buildings as porous meshes in an intermediate step, is under progress.
- The suite could work as a forecasting system. A system called MEDICIS (Achim, 2010) already exists at the lab and displays mesoscale forecasts for France.
- Then, the MM5-NSWIFT-Micro-SPRAY suite could be worked within a crisis center.

Thank you for your attention

Computation times

Domain	Software	Computation time	Machine
D01 to D05	MM5	6 hours / simulated day	Cluster 16 core
N01	NSwift	3 min	Pentium IV 2,8GHz 2,0 Go RAM
N02	NSwift	2 min	
N03	NSwift	3 min	
N04	NSwift	30 min	

Dispersion	Micro-SPRAY	4 hours	Pentium IV