



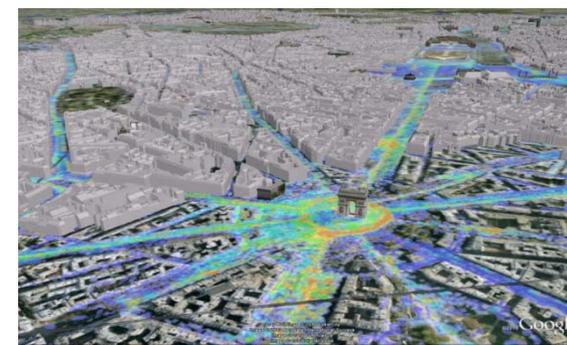
AIRCITY: A VERY HIGH-RESOLUTION 3D ATMOSPHERIC MODELING SYSTEM FOR PARIS.

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**HARMO 15 - Madrid
May 6th- 9th, 2013**





AIRCITY Partners

Combining public labs and SMEs skills



ARIA Technologies - SME

Project lead. Main modeling technology provider.
International dissemination.



CEA - French Atomic and Renewable Energies Agency

Emergency response applications. Scientific background. High Performance Computing skills.



AIRPARIF - Paris Air Quality Management Board

Traffic data, emissions, monitoring data, validation. Dissemination of results.



LEOSPHERE – SME - LIDAR Instruments Manufacturer

Field experiments



MOKILI – SME

Environmental consultant – Modeling expert.



IGN – French National Geographic Institute

“Numerical City” experts



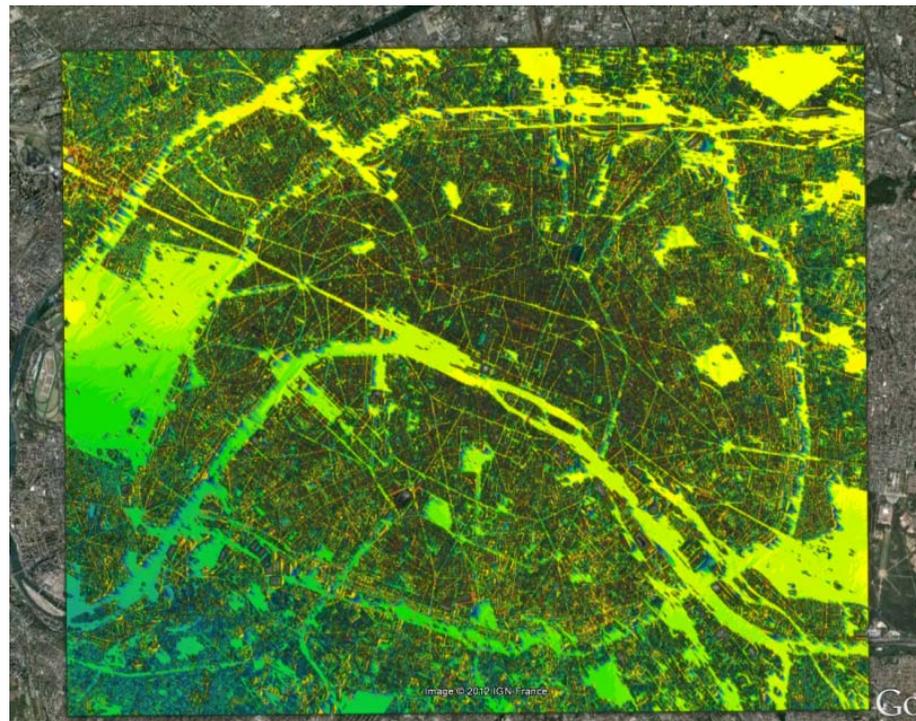


AIRCITY Project Scope

Routine high-resolution 3D urban modeling

The AIRCITY Project aims to develop a routine high-resolution air quality now-casting and forecasting tool for the City of Paris

Based on the PMSS code, the simulation system covers a **12x10km area** with **3m resolution**, and is coupled to the large scale photochemical modeling system WRF/CHIMERE.





PMSS Model

Parallel Micro – SWIFT - SPRAY

PMSS is the **parallel version** of the MSS tool, combining :

- a simplified meteorological/CFD model (**Micro SWIFT**)
- coupled to a Lagrangian particle dispersion model (**Micro SPRAY**)

PMSS is designed to model urban or industrial micro-scale dispersion phenomena **with CPU times significantly shorter than the full CFD solutions.**

PMSS is jointly developed by ARIA Technologies, ARIANET, CEA and MOKILI, with the scientific R&D backup of ISAC-CNR



PMSS is included into the HPAC suite of models by DTRA (US-DOD)

- Coupled to SWIFT meteorological model
- Coupled to SCIPUFF (Particle to Puff conversion)





AIRCITY Developments

Main project challenges

- **Micro-scale simulations** of atmospheric dispersion are often performed with complete CFD/LES codes, solving the complete set of equations for the flow on very high-resolution meshes.
- **The CPU demand of full CFD flow calculations is very large**, so that only relatively small domains (about 1km) are simulated, in order to keep the execution time reasonable.
- In AIRCITY, the first technical challenge was **to run a high-resolution solver (3m cells) over the whole city of Paris**, covering a 12x10km domain. This had led to the implementation of a simplified flow model taking into account the obstacles.



AIRCITY Developments

Main project challenges

- **24 months project schedule:** end of project in June 2013
- **Modeling challenges**
 - Completing a **massively parallel** solution
 - Tackling the **generalized numerical city** input data.
 - Modeling the **effect of traffic on turbulence** in the streets
 - Introducing **simple sets of chemical reactions**, or of nuclear transformation reactions
 - Modeling **the effect of urban canopy (river, trees)** at the micro-scale, with directional porosity
- **Validation with both LIDAR and conventional sensors**, with an Urban Field Experiment in Paris.
- **Creation of appropriate display and post-processing tools.**



AIRCITY target applications

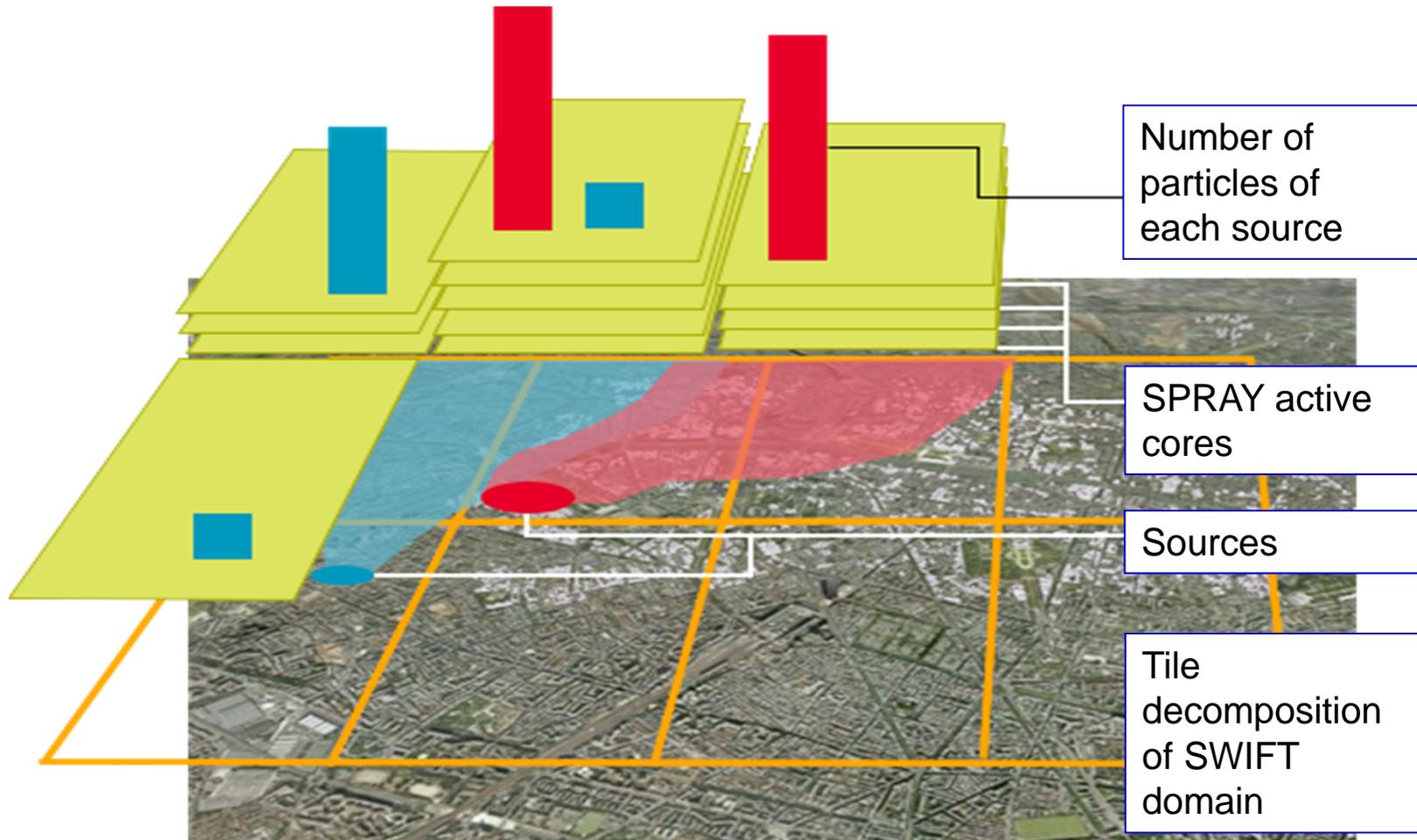
Large cities with high-resolution (3m)

Objectives

- Allow the simulation of **arbitrarily large** horizontal Urban domains, for very large cities through the concept of adjacent “flow tiles”, and the use of distributed memory.
- Real-time **Urban Emergency Response** for French cities
 - Pre-computed analysis and forecast meteorology (MM5, WRF) : 1km resolution
 - Pre-computed Parallel Micro-SWIFT solution : City-Wide, Multiple tiles, 3m resolution
 - On-line Parallel Micro-SPRAY operation in any event
 - Tested with the Paris Fire Brigade in ‘exercises
- Application of PMSS to routine air quality problems:
 - Air Quality impact of **all NOx line sources over a large city (AIRCITY Project)**
 - Electrical Vehicles penetration in **Roma (RENAULT)**

Parallel version of MSS

General scheme



Separate parallel architecture for Micro SWIFT and Micro SPRAY



AIRCITY Computer Architecture

MPI fully scalable solution



AIRPARIF
Affordable cluster (16 cores)

CEA
Large HPC (> 2000 cores)

And the PMSS code runs on a laptop....





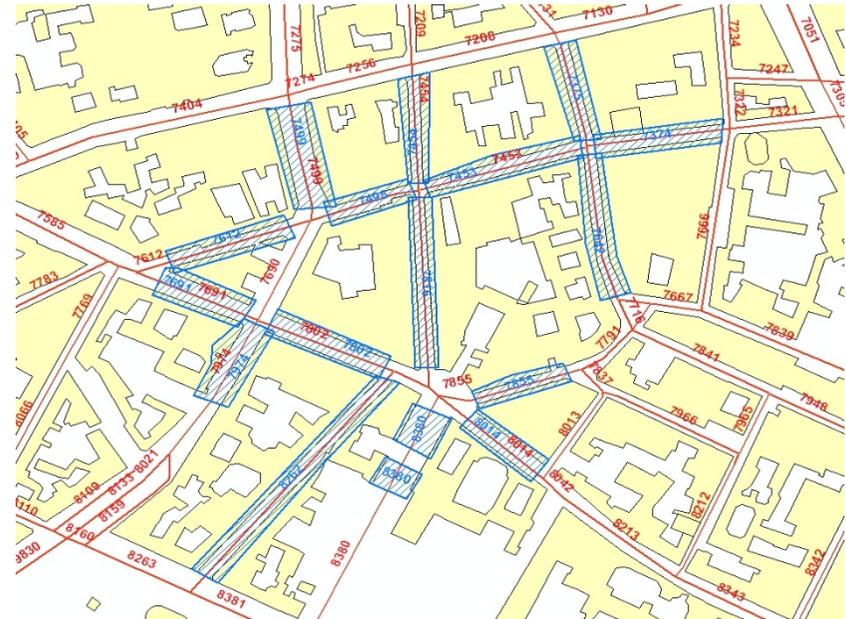
AIRCITY: Generalized “numerical city” input

Buildings, and trees, and traffic...

MSS Building file extended to *.CSV , XML compatible structure

Additional structures:

- Buildings
- Canyon zones (narrow streets)
- Tree areas
- Traffic data
- Drives turbulence diagnostics



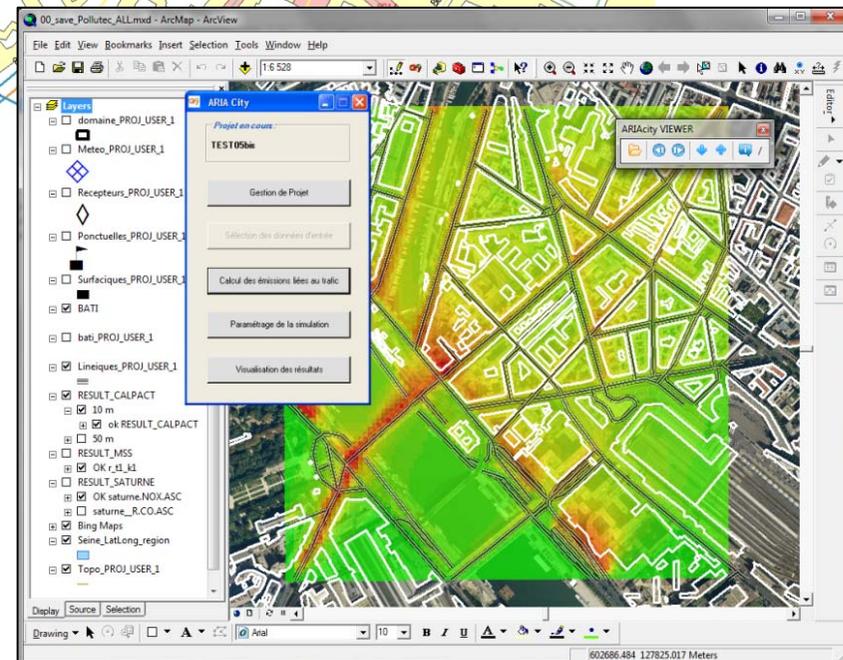
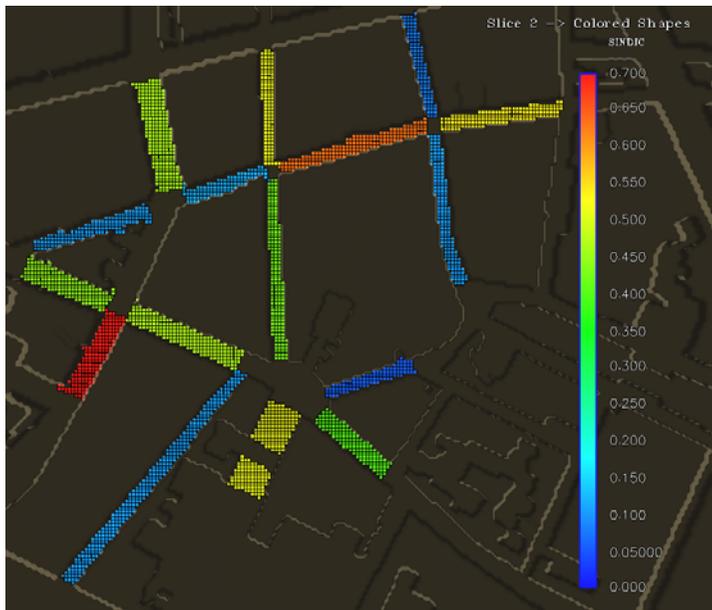


AIRCITY: Generalized “numerical city” input

Buildings, and trees, and traffic...

ArcGIS tool :

- Minimal manual editing needed
- Link to transportation models





Effect of traffic on turbulence

A key problem in micro-scale models

Look at the turbulent wake of this racing car....
What about a city bus with much worse Cx ?





Effect of traffic on turbulence

A key problem in micro-scale models

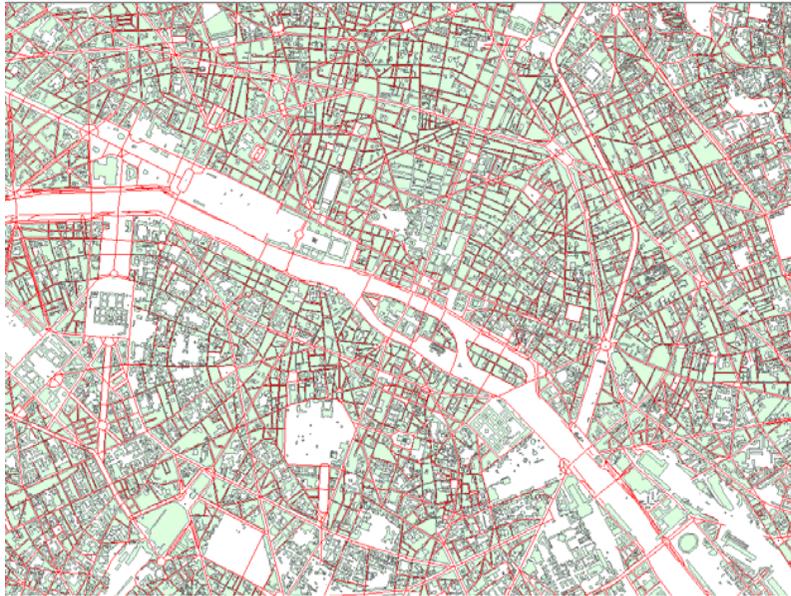
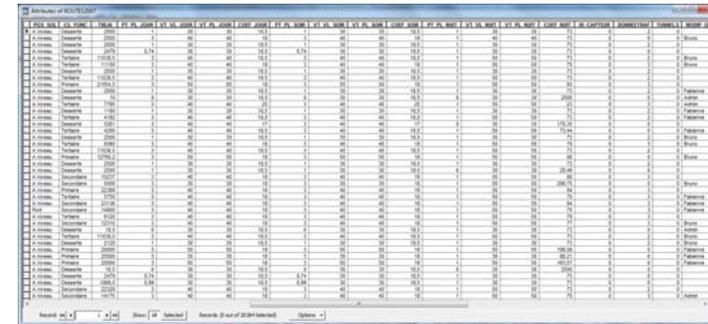
Urban simulations of air quality (NO₂, Benzene, PM 2.5) require a good knowledge of traffic, for emissions computations.

Traffic information may be used in canyon streets to estimate **traffic-produced turbulence (TPT)**.

Without TPT, the concentrations computed near surface in narrow streets are generally overestimated.

Effect of traffic on turbulence

A key problem in micro-scale models




Simple chemical reactions set

A need for NO/NO₂ estimates

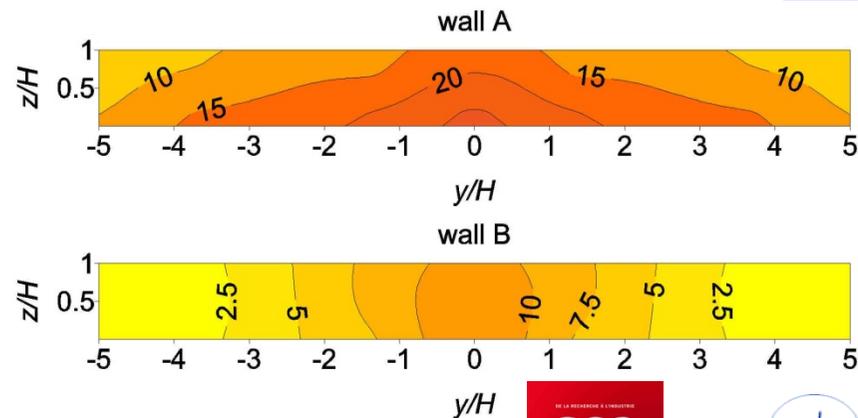
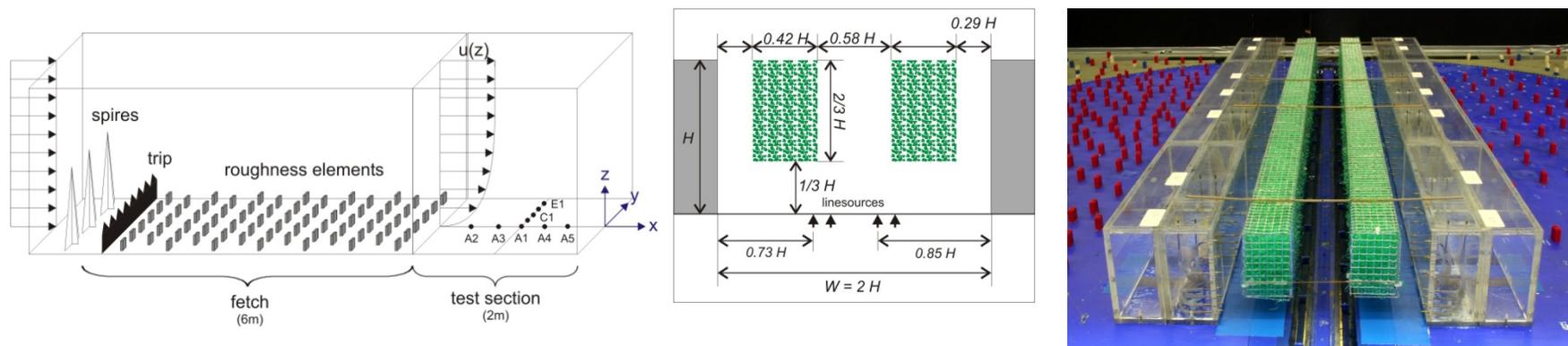
- In near-field for air quality managers, the main issue is the **NO/NO₂** partition, which depends on existing background ozone (O₃). This is why coupling with meso-scale estimates (Such as CHIMERE) is important.
- The insertion of a **simple reactions set** into Micro-SPRAY is developed in cooperation with Dr. Hadassah KAPLAN (on sabbatical from IIBR).
- **See paper presented in this conference by Armand ALBERGEL (H15-156).**
- Statistical NO_x to NO₂ tables derived by AIRPARIF for Paris stations can also be used.

Effects of urban canopy (river, trees)

Porosity and drag as first step

- **CODASC experiments** (*Laboratory of Building- and Environmental Aerodynamics Karlsruhe Institute of Technology*) show a **significant effect**
- See paper on **SWIFT canopy** by **Olivier OLDRINI** (H15-149) in this Conference

CODASC setup





AIRCITY Experimental setup

Wind + Aerosol LIDARs



3D scanning wind LIDAR



AEROSOL LIDAR (Horiz. Scans)



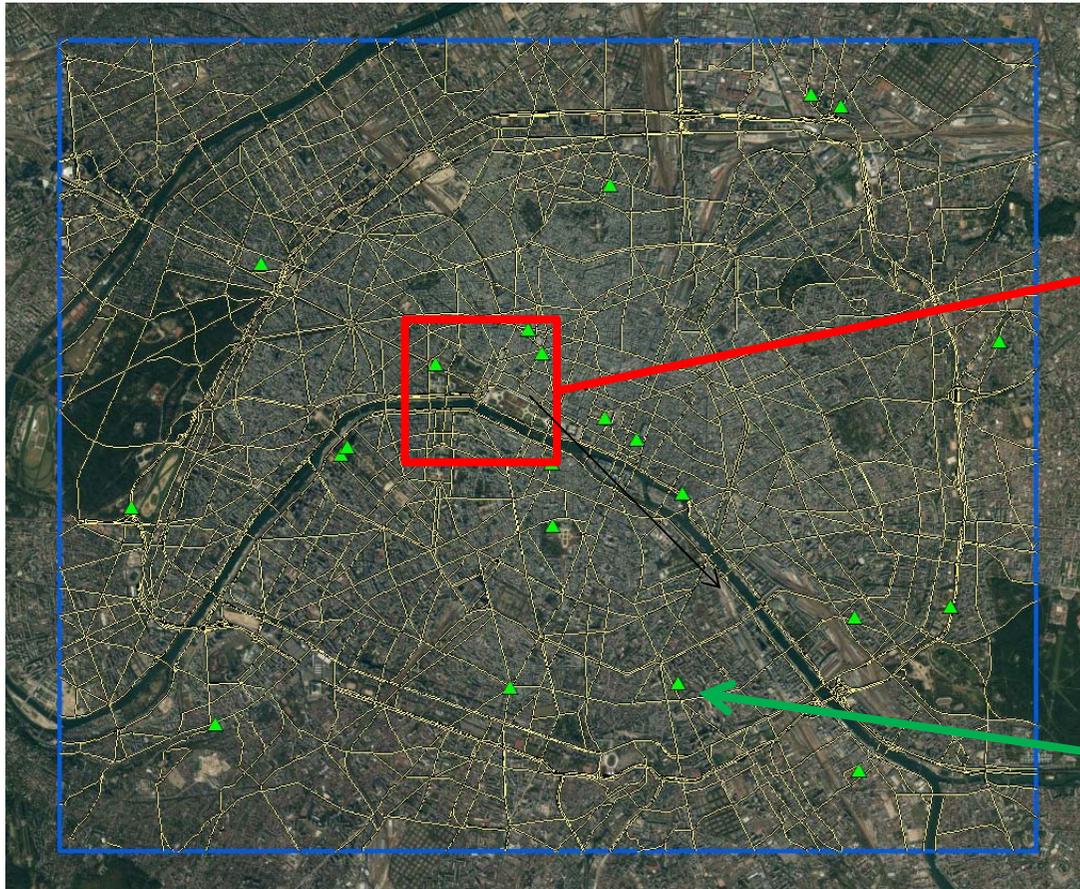
LIDAR covers 1km² area including Paris ring





AIRCITY Domains

AIRPARIF measurement stations



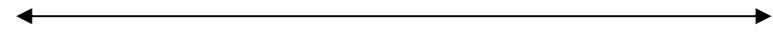
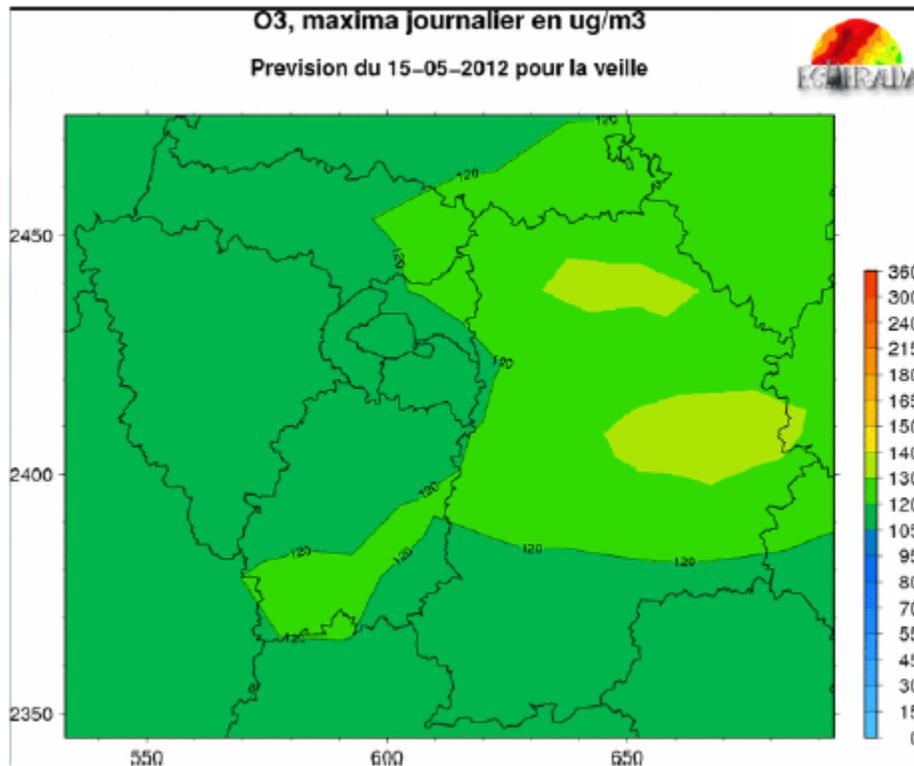
12 km



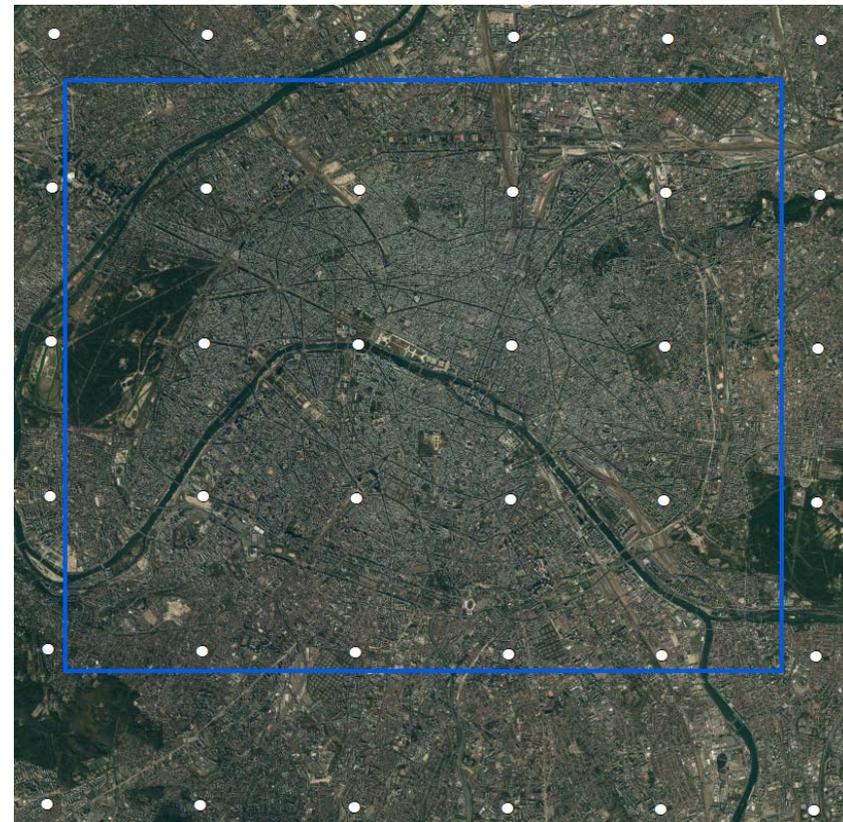


AIRCITY Air Quality downscaling

CHIMERE regional scale down to 3km resolution



12 km



150 km





AIRCITY Visualization tools

Web data mining is ready



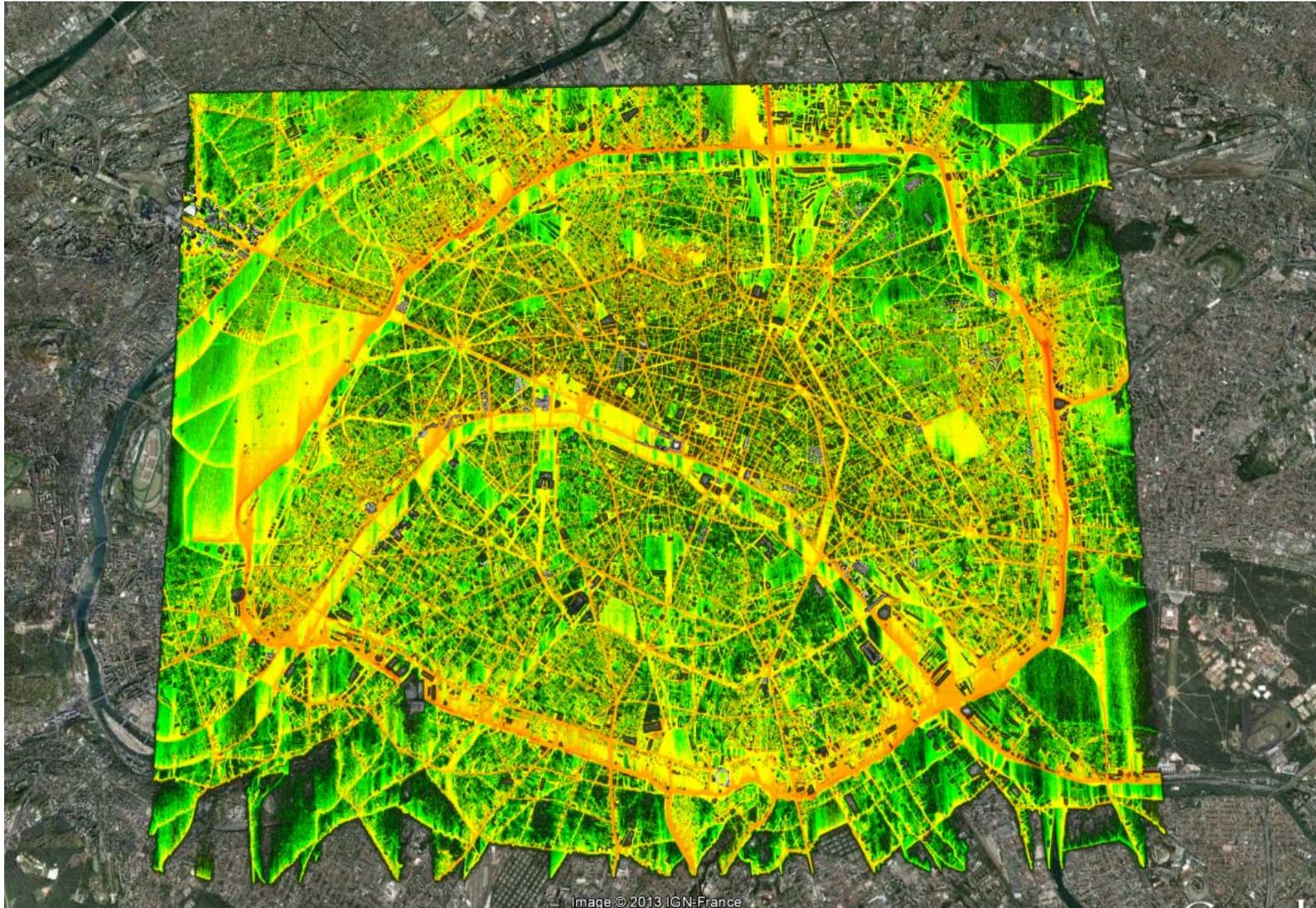
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AIRCITY Visualization tools

Web data mining is ready



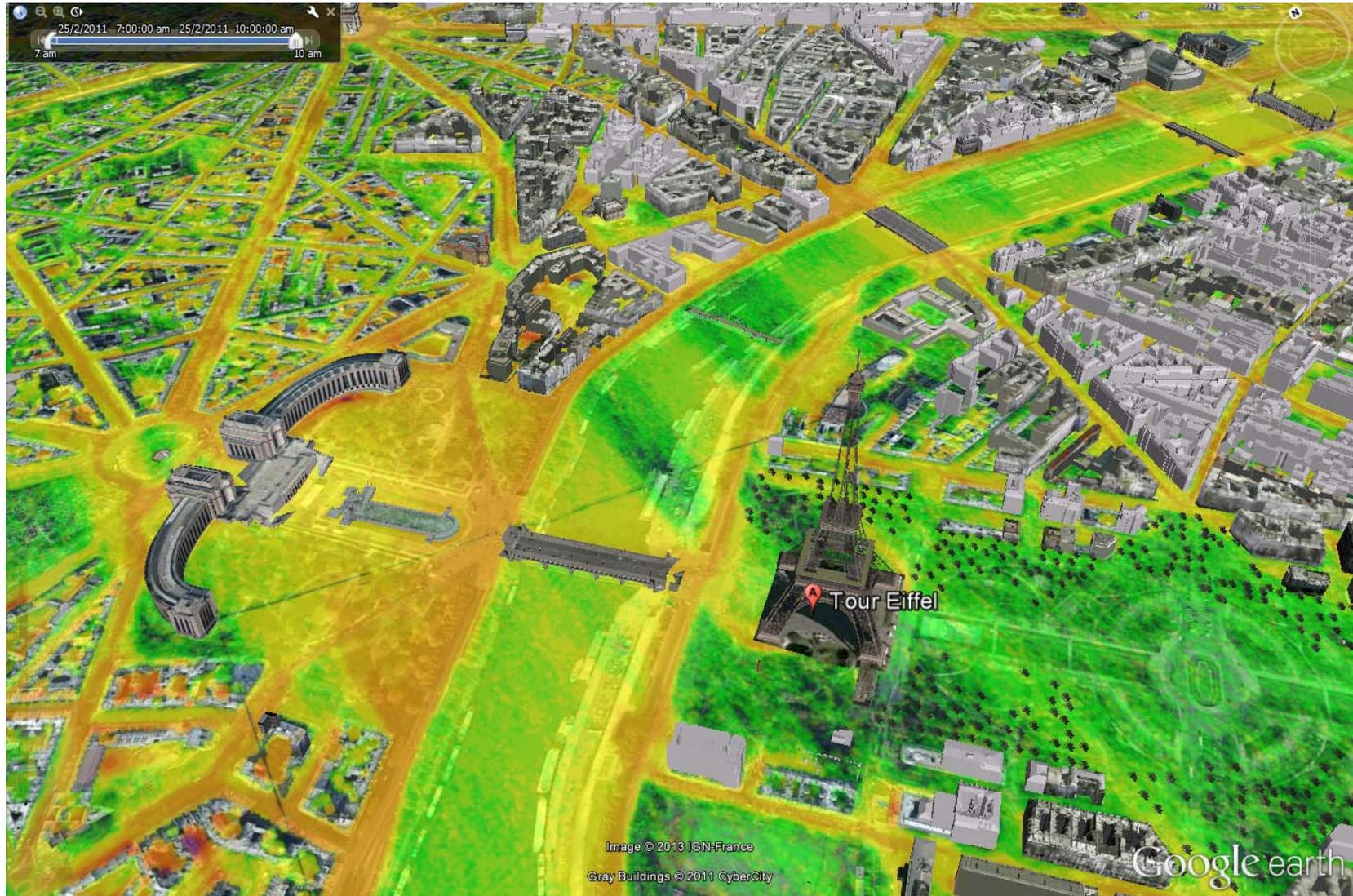
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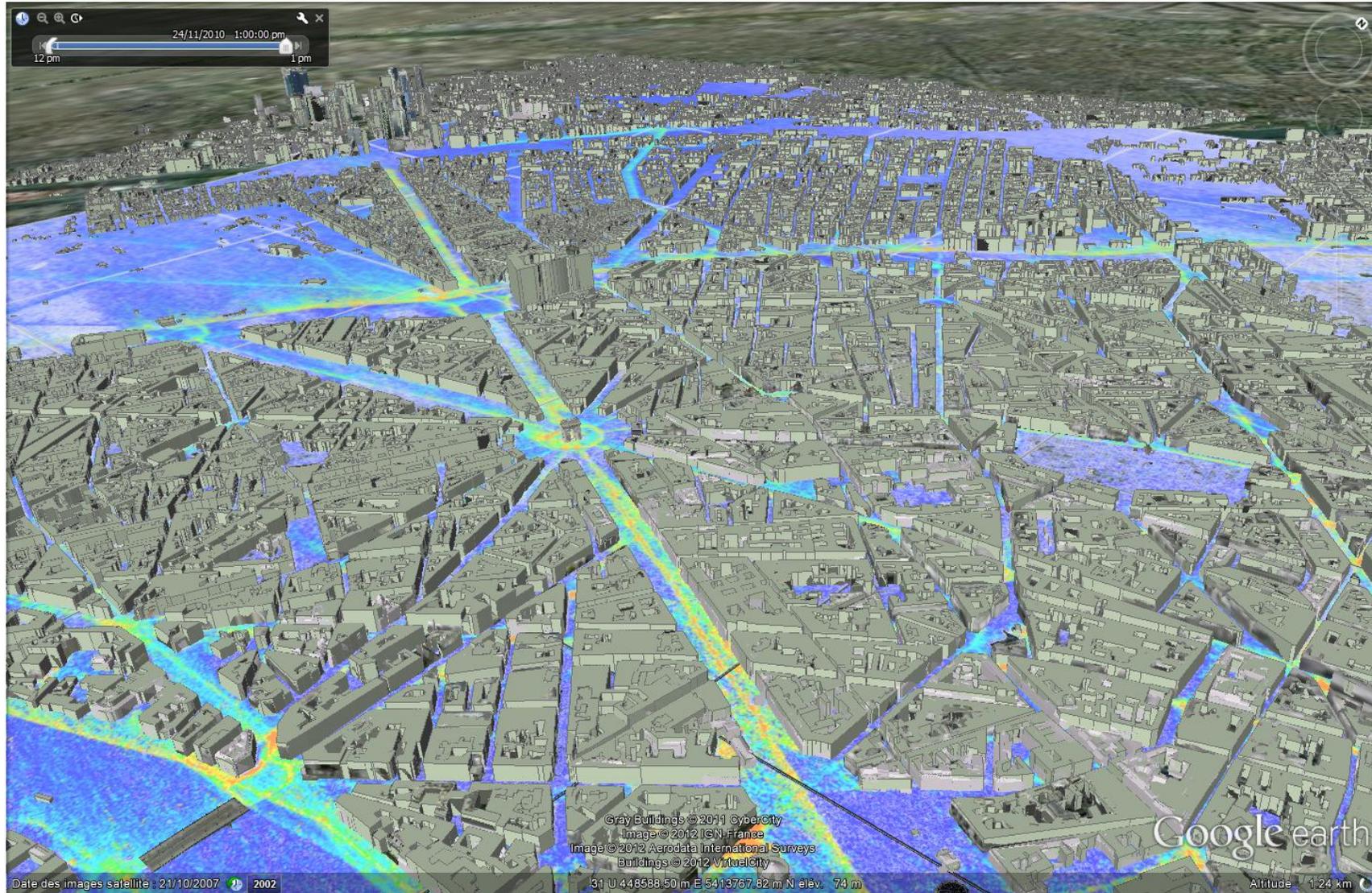
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AIRCITY Visualization tools

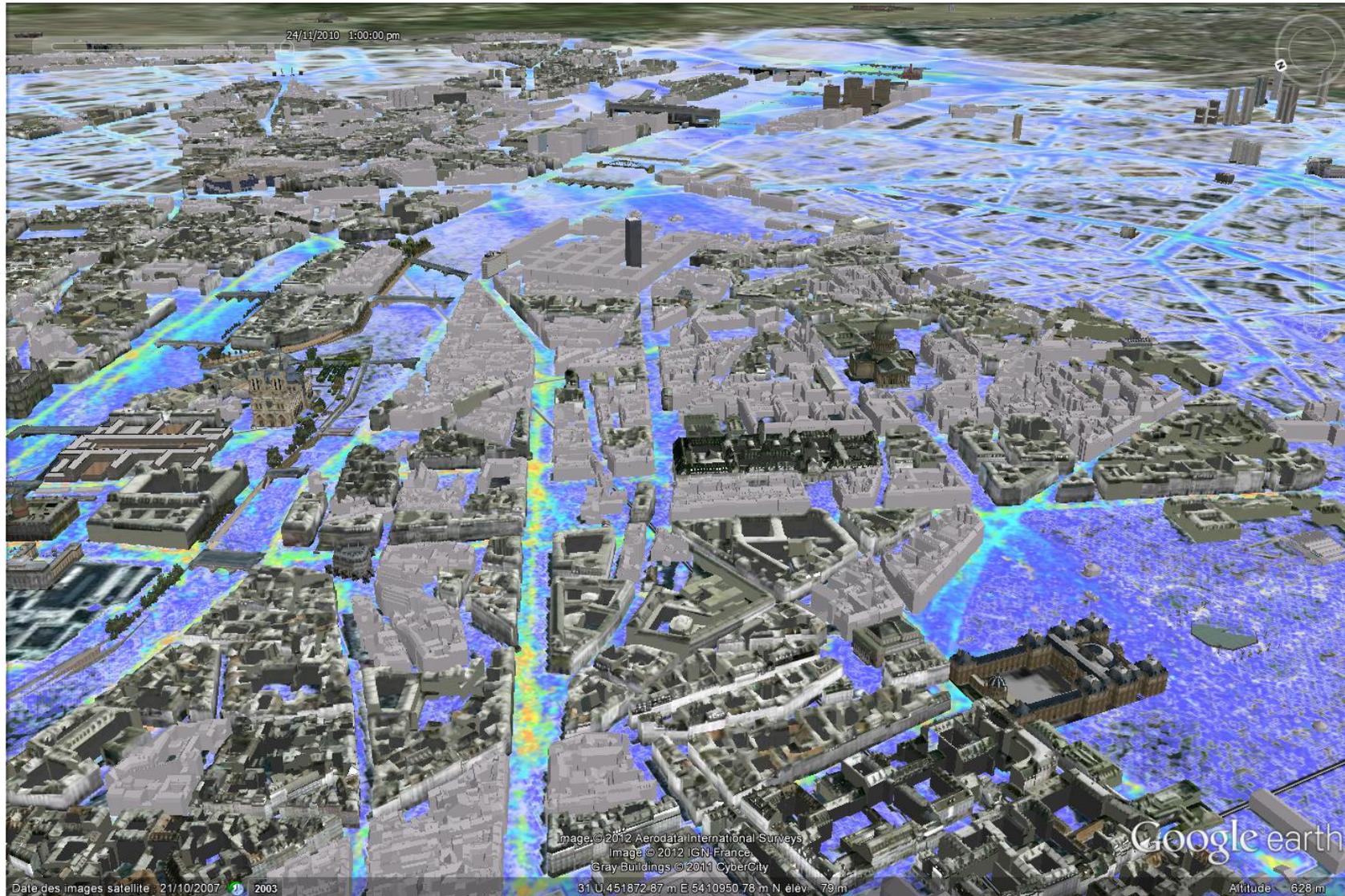
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AIRCITY Visualization tools

Web data mining is ready





AIRCITY Visualization tools

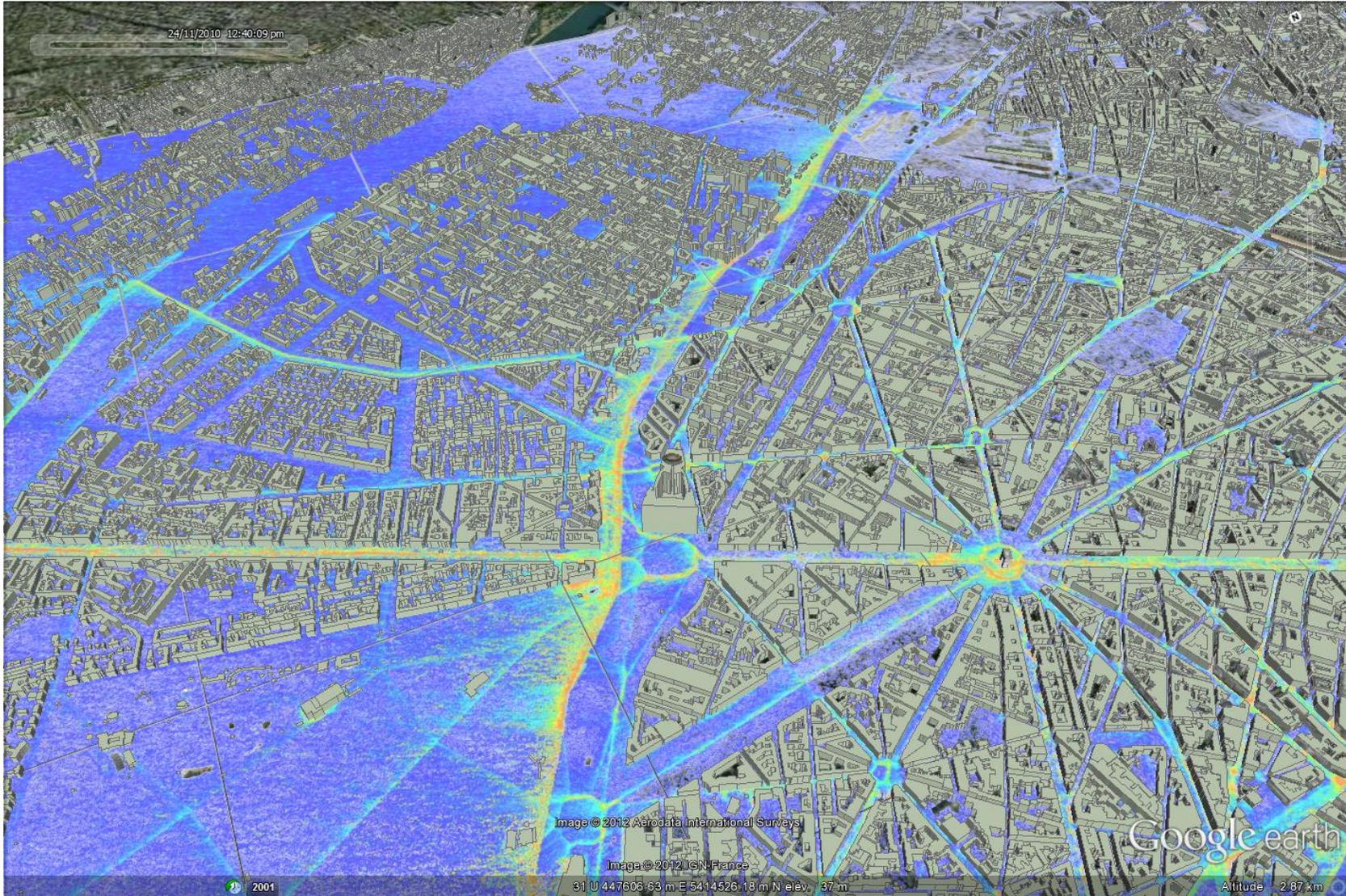
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AIRCITY Visualization tools

Web data mining is ready



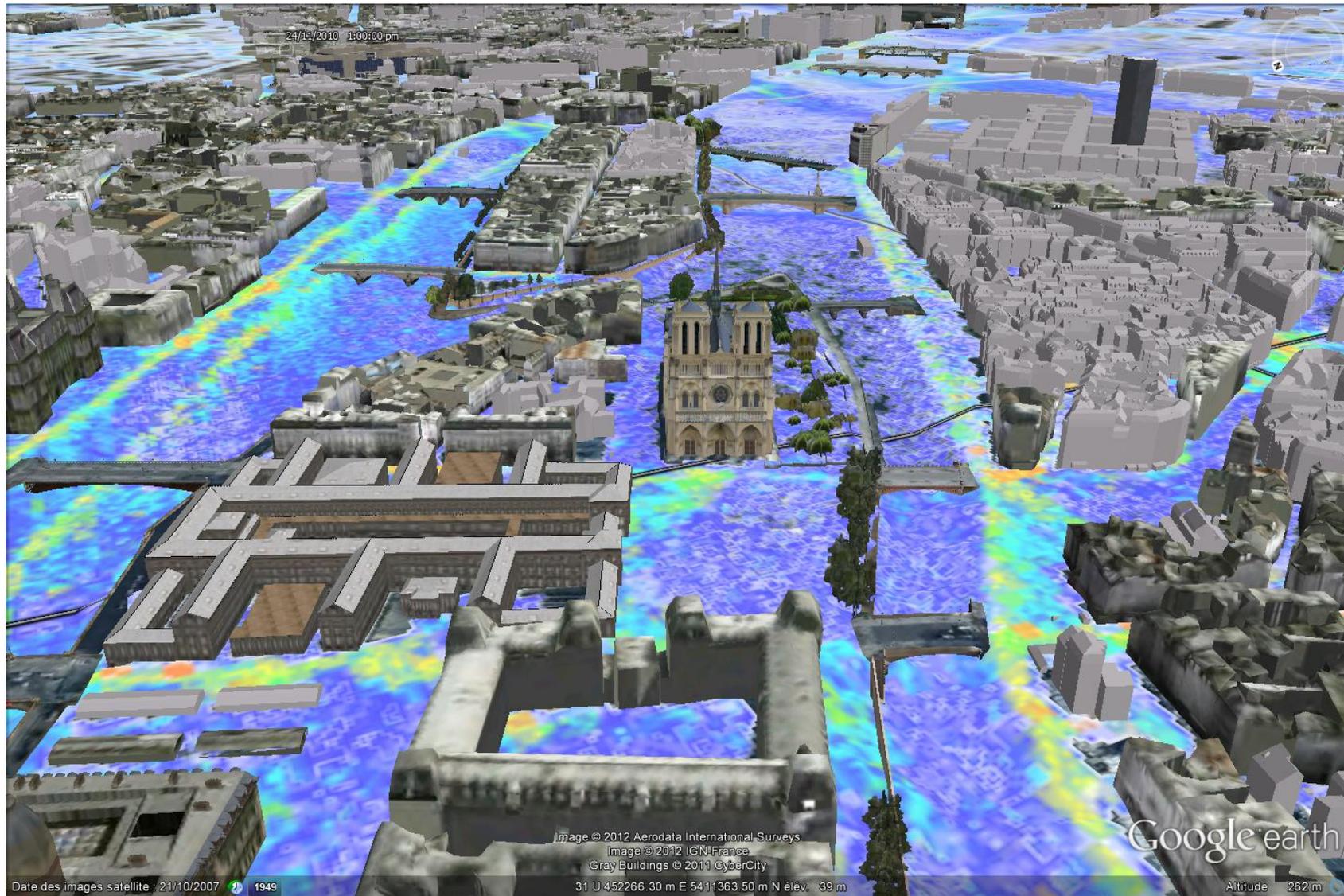
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AIRCITY Visualization tools

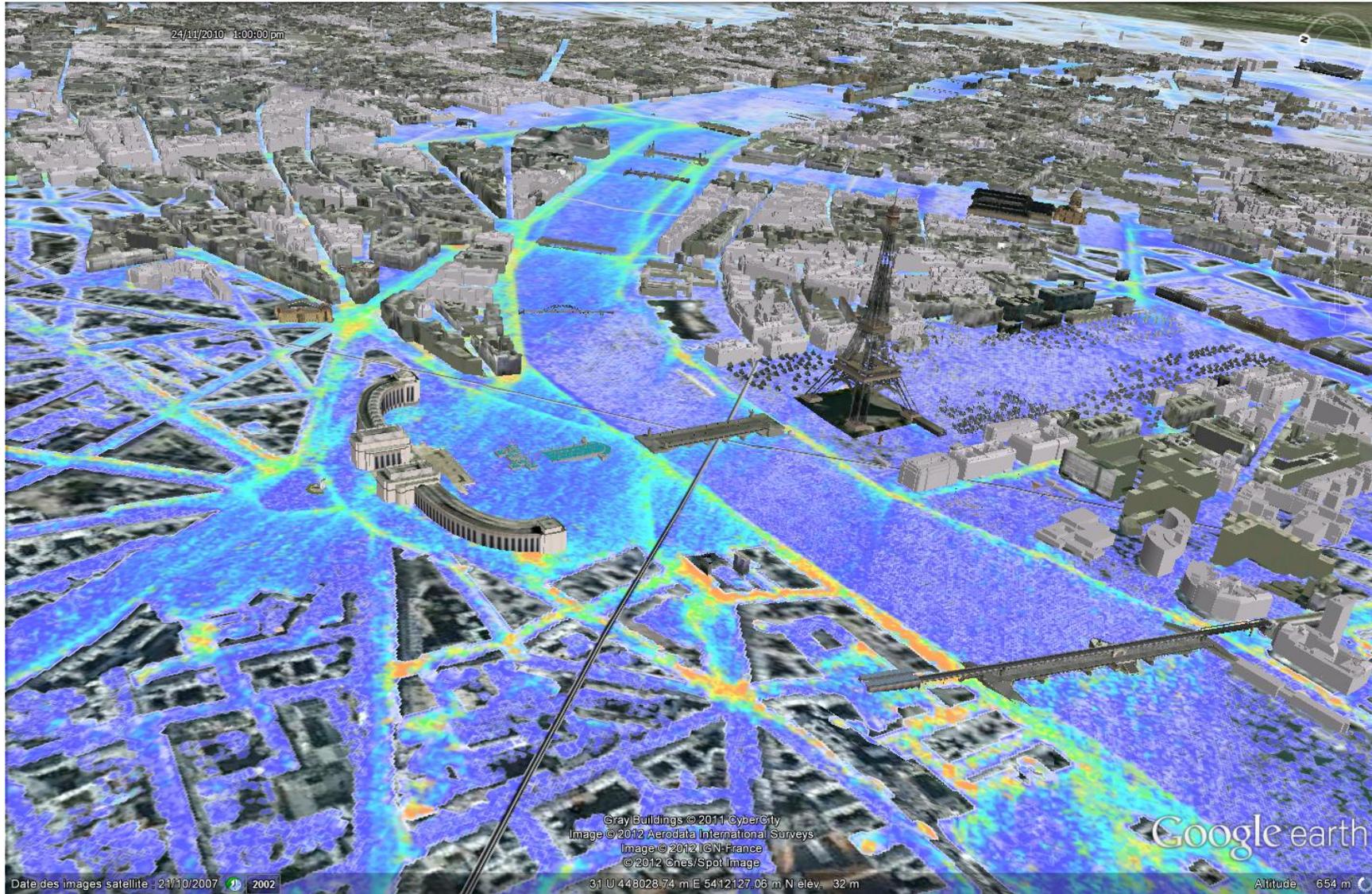
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AIRCITY Visualization tools

Web data mining is ready



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AIRCITY Project achievements

And work in progress

- **Traffic Produced Turbulence** proves important in air quality applications
- **Massively parallel version: very large urban applications** are manageable with PMSS
- **Directional drag** operational
- **Chemical reactions** operational
- **Post-processing and Web display** are ready
- **Validation** by AIRPARIF in progress



AIRCITY

Acknowledgements



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Advancity Competitivity Cluster



Conseil Régional de l'Essonne

Thank you for your attention

