



**Barcelona
Supercomputing
Center**

Centro Nacional de Supercomputación



Modelling Urban Air Quality (MUAQ)

A proposal for the 2016-2019 BSC
Severo Ochoa Programme

Earth Sciences, CASE and Computer Sciences Departments
Albert Soret, Arnau Folch, David Carrera,
Oriol Jorba, Marc Guevara and Francisco Doblas-Reyes



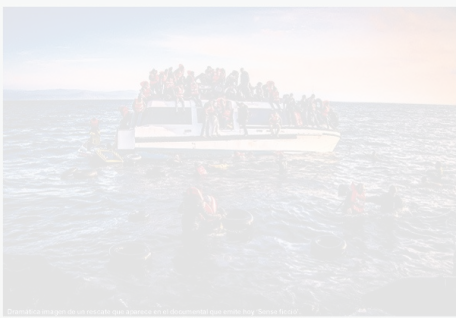
LA LIBRE CIRCULACIÓN DE PERSONAS, EN CRISIS | TEMA DEL DÍA
 «Página 2 y 3 y suplemento»

Europa se trocea

Los Veintiocho abren la puerta a mantener dos años el control de las fronteras

Grecia replica a la presión de la UE y se niega a «ahogar» a mujeres y niños»

ESTA NOCHE, EN TV 2
 La angustia de refugiados y socorristas en Lesbos



Refugiados en un bote en el mar de Egea. EFE / Getty Images / Reuters / Contrasto

Sánchez echa otro pulso a los barones

Rajoy y Rivera deciden iniciar contactos en busca de un acuerdo de gobernabilidad

Fran Rivera torea con su hija de 4 meses en brazos



MODELOS CONTAMINANTES
El área de BCN planea vetar dentro de dos años los coches diésel antiguos

COBAS DE LA VIDA • Páginas 32 y 33

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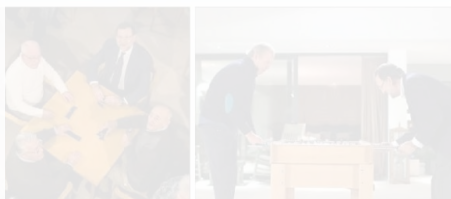
Madrid, Martes, 16.30 horas
 Ayuntamiento no descarta elevar las restricciones y mantiene la limitación de 70 km/h en la M-30 y en los accesos a la ciudad

EL MUNDO

«La ciudad es el barón de los negocios» (Margarita de Youvenberg)

El TC liquida la resolución soberanista por la vía rápida

El Tribunal resuelve declarar inconstitucional el acuerdo de «desconexión» del Parlament • El Govern scurre ante el Supremo • La UP no decidirá si apoya a Artur Mas después del 20-D



VEN DOMINGO, MEY FUTEBOLERO. Mariano Rajoy volvió ayer al voto de los centros. Durante su visita a los hospitales combates de Olinda y resurrección de la izquierda, después de haberse en el hogar del gobernador...

ENRIQUE CARRILES. En un momento con el líder opositor
«Venezuela es una bomba que está a punto de explotar»

DANIEL LEGIDO. MARIANA COMENZARÁ
 El gobernador del estado de México, Daniel Legido, visitó a la presidenta de México, Claudia Pineda, en su residencia...

estamos a favor de los trabajos de alta tecnología, aunque estamos a favor de las pequeñas industrias y de los agricultores. Esta noche nos reuniremos con...

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El ICO exige que los jefes de Abengoa no se lleven 20 millones de blindaje

FORO CATALÁN DELEGADO

CAMINO AL 20-D
 «El desfase se ha llevado los servicios públicos»

EL MUNDO llama la atención en la actualidad de la competición que tendrá el español Rafael Nadal...

ESPAÑA SUPERA LA TASA MEDIA DE CESÁREAS

#JUST2 CHALLENGE

IBERDROLA

“只要痛下决心 一定可以重见蓝天”

苍穹之下的北京，沉睡在阴霾笼罩的世界里，一片寂静，望着窗外，楼幢内建筑轮廓，我感嘆万千。北京，我要向你道歉！每天数百万辆汽车在道路上奔驰，排放的尾气难以计数。现在我们又到了那熟悉的场景——我相信，只要人们痛下决心，一定可以让你重见蓝天。
 ——摘自北京雾霾二小时及雾霾事件文（作者：魏善林等编辑）
 ©A2-A3

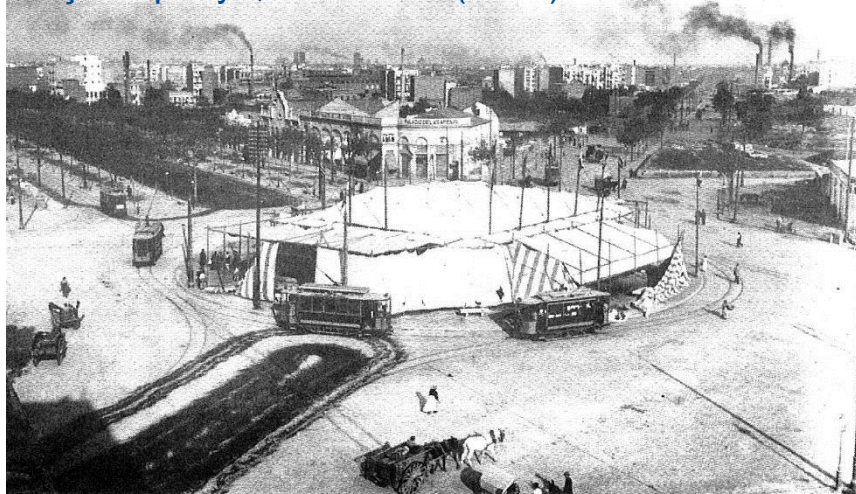
昨天北京雾霾的严重程度，北京进入雾霾天气预警最高级别，50万辆辆机动车启动限行，中小学启动停课，预计北京今天雾霾最严重时段为14时-18时，图为昨天雾霾笼罩下的北京路。

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 C C C

Urban air pollution. Causes



Plaça Espanya, Barcelona (1908)



Plaça Espanya, Barcelona (2014)



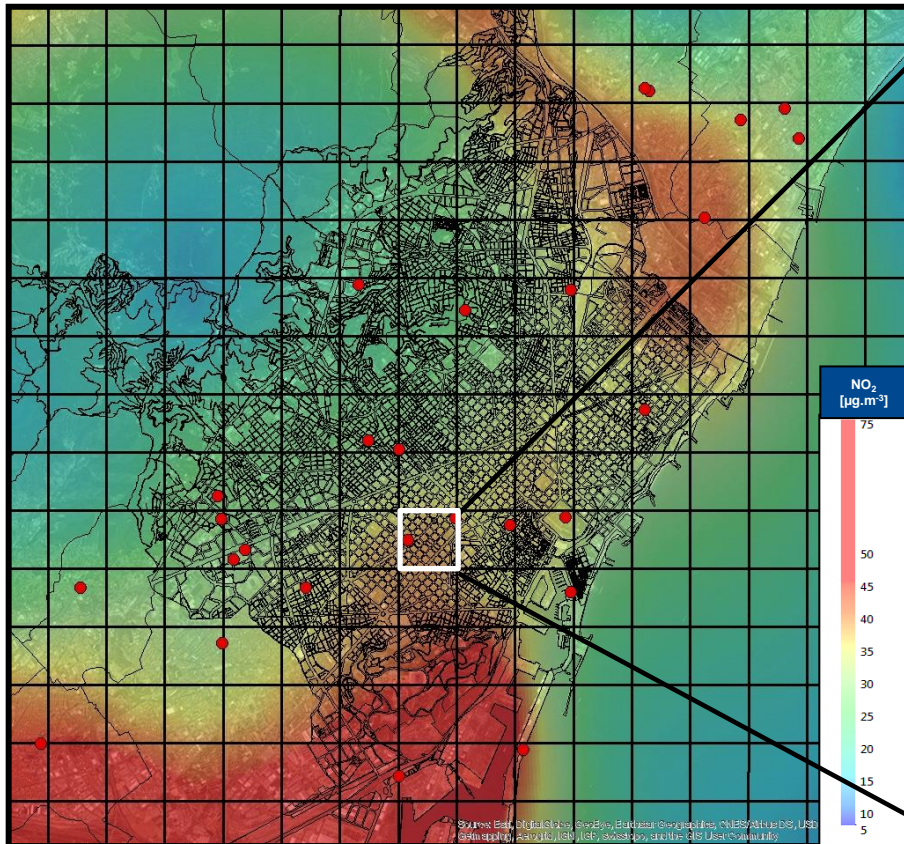
C/ Gran de Gràcia, Barcelona (1908)



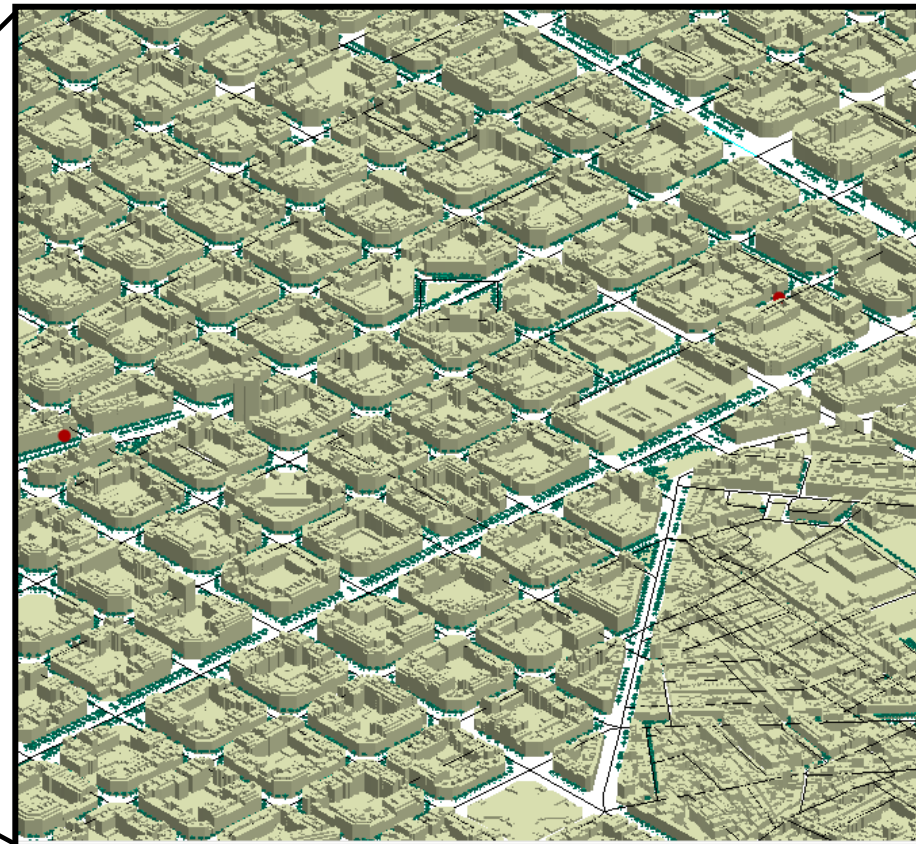
C/ Gran de Gràcia, Barcelona (2014)



Where we are now



Where we want to go



Objective

To develop, for the first time, an air quality model based on a CFD coupled to an atmospheric chemistry model at city scale enhanced by the use of Big Data technologies to assess urban air quality.

Air quality management tools: example of use case

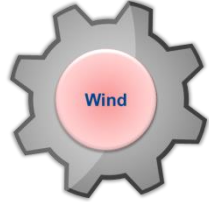


The screenshot displays the Nike+ Running App interface. On the left, a sidebar menu includes 'EXPLORE', 'CREATE', and 'MY ROUTES'. Below the menu, a 'Sort By: Most Recent' dropdown is visible. The main content area lists four top routes:

- UNIVERSITARIO EN DIAGONAL - DIAGONAL AVENUE** (2.2km): Community Stats: 1793 runners | 13767 runs
- CARRETERA DE LAS AIGÜES - AIGÜES TRAIL** (8.1km): Community Stats: 825 runners | 2677 runs
- AL LADO DE LA MAR - CLOSE TO THE BEACH** (8.8km): Your Stats: 5:01/km | 1 run
- CIUTADELLA ARC DEL TRIOMF - CIUTADELLA PARK** (2.1km)

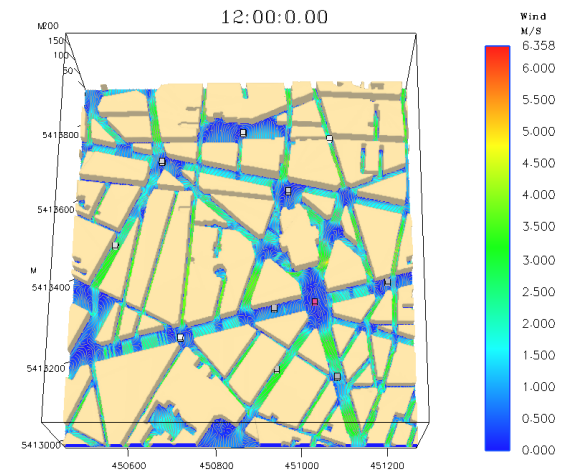
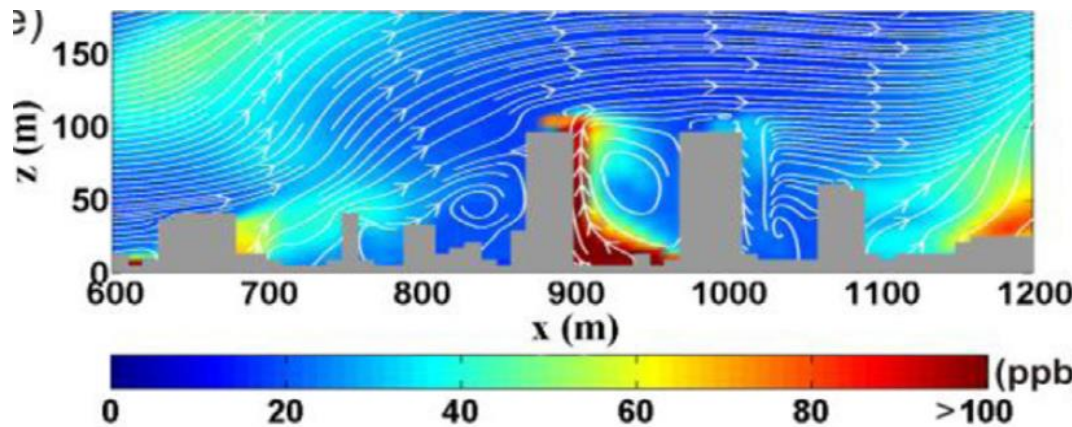
The main map area shows a heatmap of air quality over Barcelona, with red and orange areas indicating higher pollution levels. Several routes are marked with red diamond icons and their respective distances: 8.1km (B), 2.2km (A), 2.1km (D), and 8.8km (C). A search bar at the top right prompts the user to 'Enter City, State, or Postcode'. On the right side of the map, there are buttons for 'Satellite' and 'Heat Map'. The Nike logo and 'NIKE+ RUNNING APP' text are visible in the bottom right corner of the app interface.





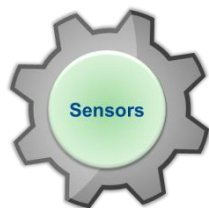
Challenge and Novelty

- High-resolution (10m) urban mesh based on LIDAR data.
- High-resolution modelling (~10m) by downscaling regional meteorological simulations to urban levels.
- CFD (Alya) runs and downscaling strategies based on transfer functions for the wind field.



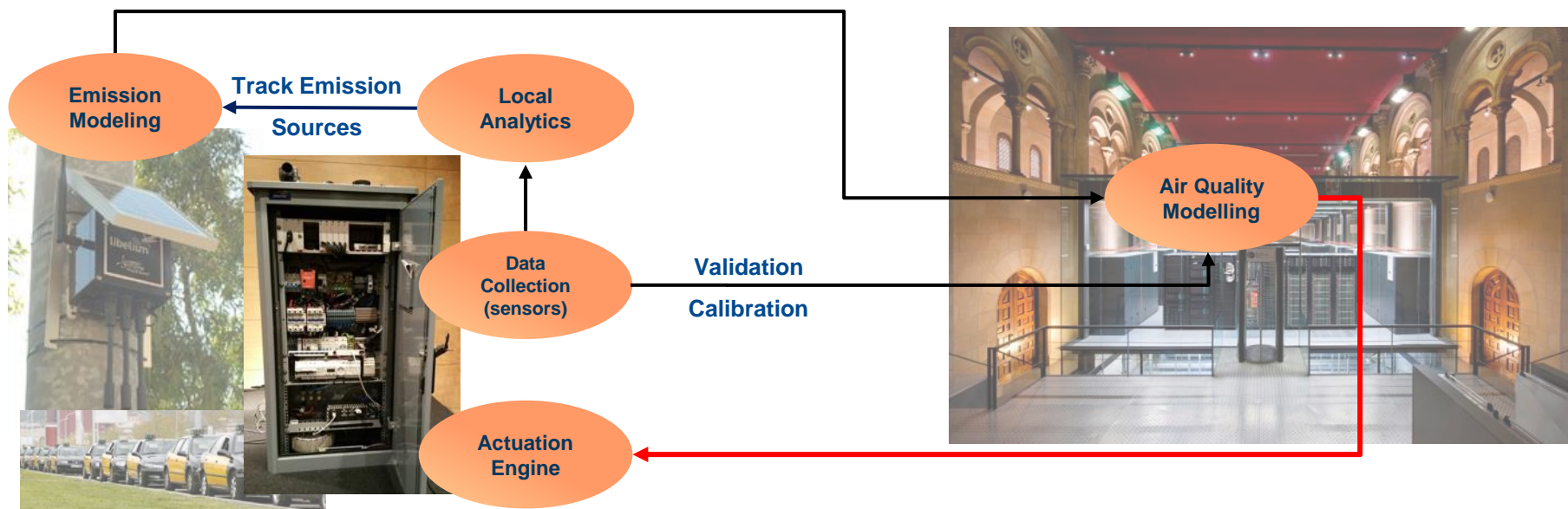
Synergies

- Aligned with H2020 lighthouse project (GrowSmarter, www.grow-smarter.eu).



Challenges and Novelty:

- Efficient collection and processing of sensor generated data
 - Requires efficient real-time data analytics under constrained network conditions
 - Manage large Volumes of Data
 - Sampling 10Hz ~720MB/day ~ 90GB/h city-wide ~2TB/day (3000 cabinets)
 - Leverage air quality models to pro-actively suggest changes in the city infrastructure
 - How can we distribute the model and the city smartness across locations?



Synergies:

- City Council and Cellnex
 - Unique opportunity
 - Barcelona pioneering this field
- Cisco Fog Lighthouse + servloTicy

Challenges and Novelty:

- Emission models based on crowd-sourced data
 - Vehicle activity data using Floating Car Data (FCD)
 - Maritime activity data using Automatic Identification Systems (AIS)
- Air quality modelling
 - Simulation of chemical and transport processes at the street level



Synergies:

- Public administrations
- Port authorities
- Research health centres
- Mobility managers

Human:

ES :	96 PM (2 postdocs x 4 years) + 36 PM (PhD in-kind ES)
CASE:	48 PM (2 postdocs x 2 years) + 12 PM (vis.+mesh in-kind CASE)
CS:	36 PM (1 developer x 3 years)
PM and outreach:	2 PM/year
TOTAL:	188 PM (approx. 240 k€/year)

Infrastructure, supercomputing resources (approx.):

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TOTAL:	4 Mh/year (substantial disk space also required)

Others:

ES :	None
CASE:	None
CS:	40 k€ to acquire sensors for model calibration
TOTAL:	40 k€

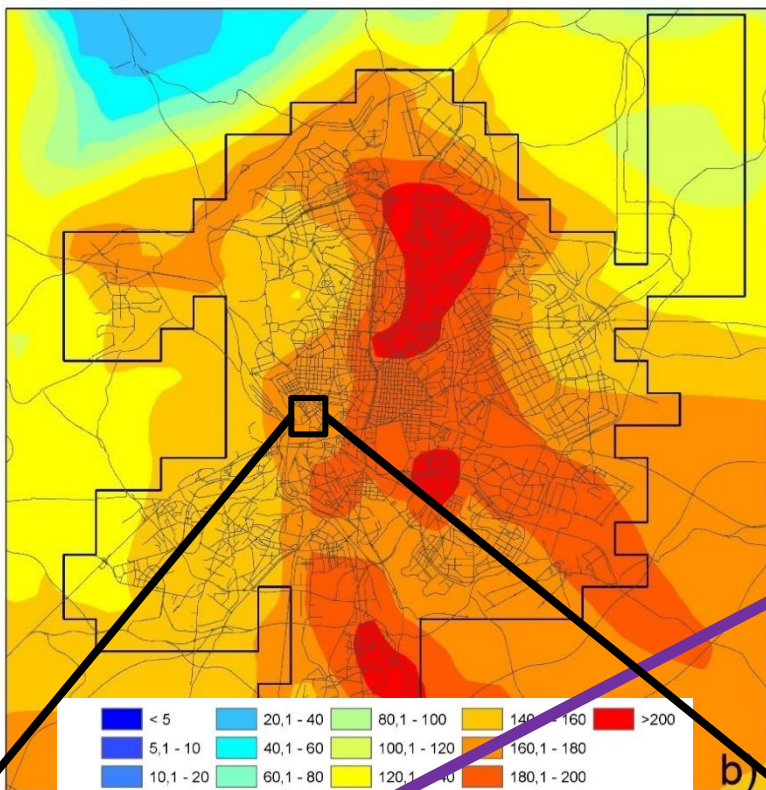
TOTAL: 250 k€/year



Why this project has to be founded?

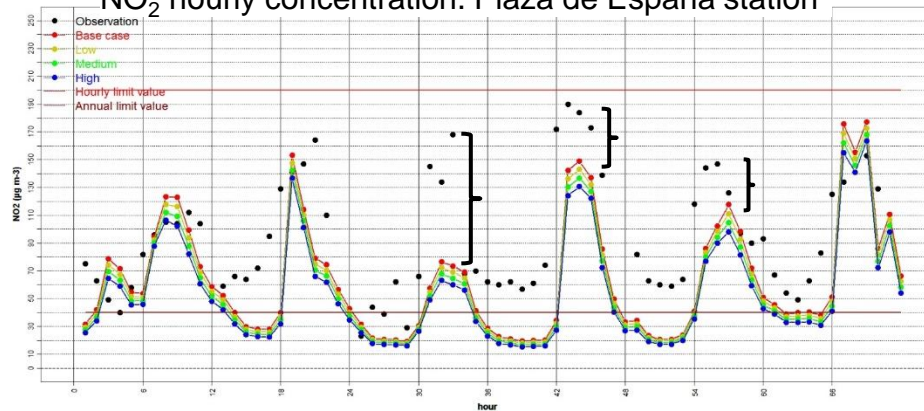
- Strategic positioning of the BSC in an emerging and interdisciplinary area with high impact on the society.
- Address health and smart sustainable policies in urban environments.
- In line with current tendencies of using new in-situ observatories (e.g. floating car data) to strength air quality modelling capabilities.
- Industrial companies are interested in air quality data for Smart Cities applications (e.g. Vodafone Ciudad Conectada)

NO₂ (ug m⁻³) Max h
Base case; Madrid

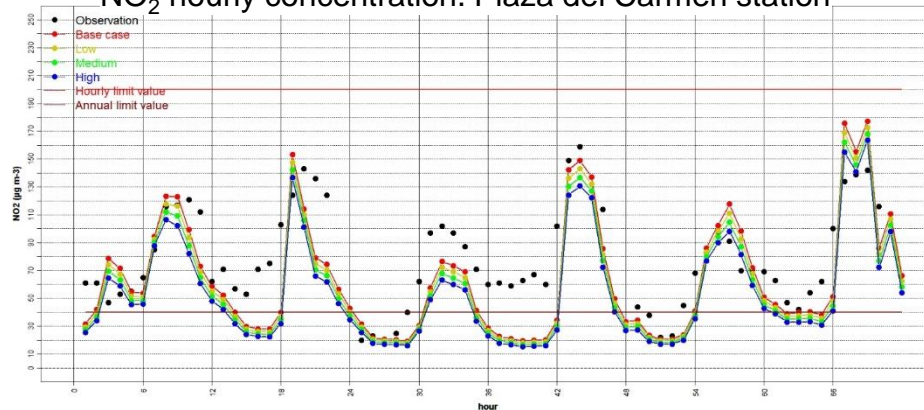


- 1) Mesoscale models (current solutions) show a satisfactory performance to simulate background concentrations (e.g. Plaza del Carmen).
- 2) However, they are not able to reproduce street-level strong concentration gradients (e.g. Plaza España located close to Gran Via); purpose-built tools are needed.

NO₂ hourly concentration. Plaza de España station



NO₂ hourly concentration. Plaza del Carmen station



Pilot area of study	Barcelona from the airport to Badalona and east of Collserola, starting with a first pilot at the Glories district.
Resolution	Spatial: 10m (~100M nodes CFD mesh for the case of Barcelona) Time step: <10 seconds. Temporal resolution of the output: hourly
Study period	The prototype will be tested and evaluated on a few selected past events
Methodology	<ul style="list-style-type: none">● Downscaling of regional air quality to street-level concentrations by means of microscale wind and pollutant transport modeling.● Use multiple, real time (whenever possible) sources of data from an urban environment (sensors, models).
Impacts	<ul style="list-style-type: none">● Improve our understanding of street-level processes within urban environments.● Address health and smart sustainable policies in urban environments.
Research questions	<ul style="list-style-type: none">● Can the estimation of main air pollutant concentrations be improved at the street level?● Can more targeted air quality information be provided for exposure studies?● How to make the most of emerging smart sensor deployments and new approaches to information discovery and display?

Outcomes and strategic positioning



<p>Expected outcomes</p>	<ol style="list-style-type: none"> 1. Emission model with nearly real-time estimation of traffic emissions. 2. Microscale model based on Alya to simulate pollutant dispersion and chemistry at street level that can be transposed to other cities. 3. Mid-term: assessment of urban environments for healthy and sustainable urban planning (scenarios). 4. Mid-term: high-resolution nowcasting of air pollution at urban level. 5. Long-term: hourly forecast of air pollution at urban level
<p>Expected benefits for BSC</p>	<ol style="list-style-type: none"> 1. Science: positioning in a re-emerging area, capitalising on a strong inter-departmental collaboration. 2. Outreach: design of products with high social and media impacts, opportunity for popular involvement (e.g. a measurement campaign using air quality sensors involving BSC staff, UPC students, etc. is planned) and for gaining social visibility.
<p>Stakeholders (a selection)</p>	<ol style="list-style-type: none"> 1. Public administration: Barcelona city council, Generalitat. 2. Research health centres: CREAL, ISCIII 3. Telecommunication companies: CELNEX (Abertis) 4. Mobility managers: Barcelona city council, TMB, RACC 5. Urban ecology and sustainable development: ICTA <div style="text-align: right;">     </div>
<p>Strategic positioning</p>	<ol style="list-style-type: none"> 1. Engage other research centres for leading consortia to apply to future H2020 and other national, European and international instruments. 2. Leading position for future H2020 calls: SC5-19-2017: Coordination of citizens' observatories initiatives; MG-7.3-2017: The port of the future.

State of the art. What the community is doing in modelling urban pollution?

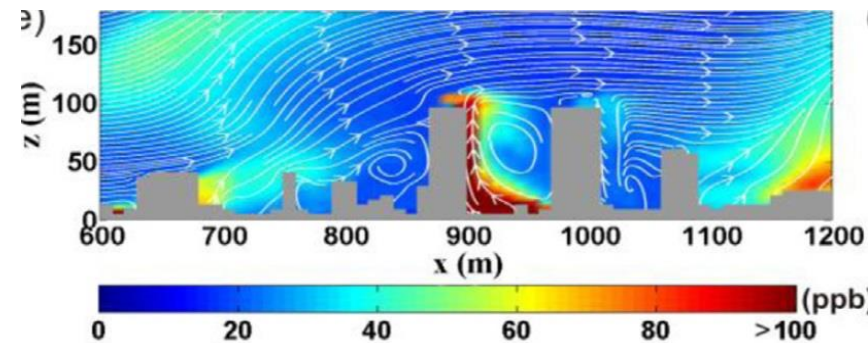


TECNIAIRE Project: UPM and CIEMAT are working in the development of a CFD for air quality. Their objective is to develop a model to simulate specific streets and crossroads in Madrid. Funded by the Spanish Ministry (MAGRAMA).

Added value: the BSC-OS2 project simulates the whole city to develop a comprehensive tool (i.e. considers remote impacts) for air quality planning purposes.

Kwak et al., 2015 This work presents a CFD model for air quality implemented in Seoul. The domain of study is only a high-rise building area, and the period of study is only 6 hours.

Added value: the BSC-OS2 project unique interdisciplinary team will allow (thanks to its scalability) the simulation of several days to analyse different patterns and differences between day and night.



TNO: Development of their own microscale model, the URBIS model (Gaussian). In their new strategic plan their objective is to use smart sensors but no CFD.

Added value: the BSC-OS2 project combines both a detailed microscale model based on a CFD approach coupled to a chemistry model and innovative data-capturing technologies.

Earth Sciences Dep.

Computer Sciences Dep.

CASE Dep.

WP1

Mesoscale model
experiment

Gaussian model
experiment

WP3

Meteorology (CFD)

Transport (CFD)

Photochemistry

CFD model
experiment

WP2

Emission
model

FCD*

Sensors

Evaluation

WP4

User engagement, applied
communication and dissemination

Visualization

Big data back-
ends for earth
sciences

Define future cases of study.
Proof of concept: modelling tool
forecast air urban quality

*Floating car data for on-road
and maritime transport

Gantt Chart		M1-6	M7-12	M13-18	M19-24	M25-30	M31-36	M37-42	M43-48
WP1. Mesoscale and Gaussian experiments									
1.1 Mesoscale model									
1.2 Gaussian model									
WP2. Efficient emission modelling									
2.1. First emission inventory									
2.2. Sensors for emission inventory purpose. FCD									
2.3. Detailed emission inventory; use FCD.									
WP3. CFD air quality experiment									
3.1. Pre-processing (meshing strategies)									
3.2. CFD and transport module									
3.3 Air quality module (chemistry)									
3.4 CFD model experiment									
WP4. User engagement/comm./dissemination									
4.1 Big data back-ends for earth sciences									
4.2 Visualization									
4.3 Define future cases of study. Proof of concept.									

WP1. Mesoscale and Gaussian experiments



WP1	Mesoscale and Gaussian experiments
Participants	Earth Sciences Department
Objectives	<ul style="list-style-type: none">• Define the period of study.• Perform mesoscale model simulations.• Apply current strategies to simulate microscale processes (Gaussian models).• Evaluate model results (both: mesoscale models and microscale models based on Gaussian approximations) with current observational data sets (air quality monitoring stations).• To establish a model benchmark.
Integration with the rest of the project	<p>The results of this WP will provide initial and boundary conditions for WP2 (meteorological information to properly estimate emissions) and WP3 (air quality and meteorological). Model results will be evaluated with available air quality observations in Barcelona to establish the skill of current mesoscale models to properly reproduce air quality levels at street levels. This evaluation will help to assess current model performance to depict street level concentration gradients (WP4).</p>
Means required	1 PhD student during 3 years (36 PM). In-kind contribution from BSC-ES 1 postdoc (12 PM).

WP2	Efficient modeling of emissions
Participants	Computer Sciences and Earth Sciences Departments
Objectives	<ul style="list-style-type: none">• Compile and process crowd-sourced data:<ul style="list-style-type: none">• Vehicle activity data (traffic volume, speed, fleet composition) using information from Floating Car Data (FCD).• Maritime activity data (vessel location, speed) using information from Automatic identification systems• Sensor deployments in the street as a BSC pilot• Development of a traffic and a maritime emission model• Estimate very high resolution (10m) hourly urban emissions
Integration with the rest of the project	The emissions estimated in this WP will be used to perform the micro-scale model simulation in WP3 and WP4. The emission results will be compared with other current state-of-the-art methods used to estimated emissions.
Means required	1 postdoc for 4 years (48 PM) (emission model) 1 developer for 1.5 years (18 PM) (sensors)

WP3. CFD air quality experiments



WP3	CFD air quality experiments
Participants	CASE and Earth Sciences Departments
Objectives	<ul style="list-style-type: none">• High-resolution (10m) urban mesh based on LIDAR data.• CFD (Alya) runs and downscaling strategies based on transfer functions for the wind field.• Implement the pollutant transport module.• Implement the air quality module following the model chain of the NMMB model.• Perform microscale model simulations for the period of study.• Evaluate new air quality sensors with current the observational network.• Evaluate model performance to simulate street-level concentration gradients and related hourly maximum levels.
Integration with the rest of the project	This WP will focus on the implementation of the software and will perform the CFD model experiment. Strong coordination with WP1 (mesoscale modelling) and WP2 (emission inventory) is required.
Means required	2 postdocs during 2 years (48 PM) (meteorology and transport) 1 postdoc during 2 years (24 PM) (chemistry)

WP4. User engagement, communication and dissemination



WP4	User engagement, applied communication and dissemination
Participants	Earth Sciences, CASE and Computer Sciences Departments
Objectives	<ul style="list-style-type: none">• Integration with high-performance scalable data back-ends for the model data (NoSQL, Document oriented)• Visualization strategies.• Define future cases of study. Explore the applicability of the system to assess the impact of: punctual accidents in industrial sites, unexpected emissions due to port activities.• Proof of concept: modelling tool forecast air urban quality• Disseminate the project ideas and results adapting the message to each audience.• Engage with all the interested parts, to receive end-user feedback and interaction, promote capacity building and project co-design according to the real needs of the
Integration with the project	The purpose of this WP is to achieve the expected social impact of the results from the previous WP.
Means required	Project management and outreach: 2 (PM)/year. 1 developer during 1.5 years (18 PM) (data back-end) 1 postdoc during 1 year (12 PM) (case studies) 1 postdoc during 1 year (12 PM) (Visualization and mesh in-kind CASE)

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