AIRTEC-CM NEWS, NOVEMBER 2022

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Comunidad de Madrid

IN THIS ISSUE:

What is the project about? Where are we?

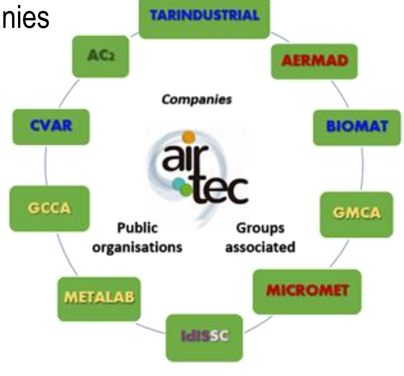
AIRTEC-CM (urban air quality and climate change integral assessment) is a scientific programme funded by the Directorate General for Universities and Research of the Greater Madrid Region (S2018/EMT-4329) and the European Union. We aim at improving our understanding of the interactions, synergies and interdependencies among biotic and abiotic agents in the urban atmosphere in a context of climate change.

While the economy is getting back to pre-COVID-19, the international community has reaffirmed its Climate targets to limit global temperature rise (IPCC, 2021). On the air quality side, the World Health Organization (WHO) has updated their ambient air quality guidelines, setting stricter goals than those of 2005 to prevent health impacts in urban areas. As a result of the scientific evidence and techno-economic analyses regarding air pollution, the European Commission is also proposing more ambitious air quality standards within the overarching European Green Deal. The research groups within AIRTEC-CM continue working to help meeting these increasingly challenging goals.

Consortium

The Consortium is integrated by:

- Technical University of Madrid (UPM)
- Energy, Environment and Technological Research Centre (CIEMAT)
- Complutense University of Madrid (UCM)
- Spanish National Research Council (CSIC)
- Health Research Institute. Hospital Clínico San Carlos in Madrid (IdISCC)
- Local administrations (air quality service of Madrid City Council and Greater Madrid Region)
- Associate companies



Objectives and Working program

OBJECTIVES and RECENT DEVELOPMENTS

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2. Impact of green infrastructure on traffic-related pollutant concentrations in urban areas

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OBJECTIVE 4: MEASUREMENT TO IMPROVE AIR QUALITY AND CLIMATE CHANGE

1. Impact of COVID-19-related restrictions on air quality
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1. Pollen calendars as a dissemination tool of the pollen exposure in the Community of Madrid
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3. Inverse modelling for estimating biotic pollutant emission factors
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1. Meteorology-normalized method to estimate the true air pollution reduction during the COVID-lockdown period
2. Study of the NO_2 and $PM_{2.5}$ exposures and their impact on the gut microbiota of healthy subjects
3. Annual weather simulation under the climate scenario 2018/2050

Objectives and Working program

Historical analysis and measurement

OBJECTIVE 1

1. AIRTEC extensive measuring campaigns

Three weeks of Summer 2021 were chosen to carry the last of the four measuring campaign within the AIRTEC Project and complete this task. A variety of monitoring techniques were used in this extensive experimental campaign to understand microscale concentration gradients in urban areas and the links between outdoor and indoor air quality. The Figure 1 shows some of the monitoring devices used in the measuring campaigns.

***Figure 1**. a) IRGASON sonic anemometer, b) CPCs, Grimm EDM 365, Black Carbon sensors, Ozone and NOx monitors, c) KUNAK device, d) PDTs, e) DUO SAS Super 360 (VWR), f) Turbulence-meteorological station, g)Thermo Scientific 42i"*

1.1 Meteorological conditions

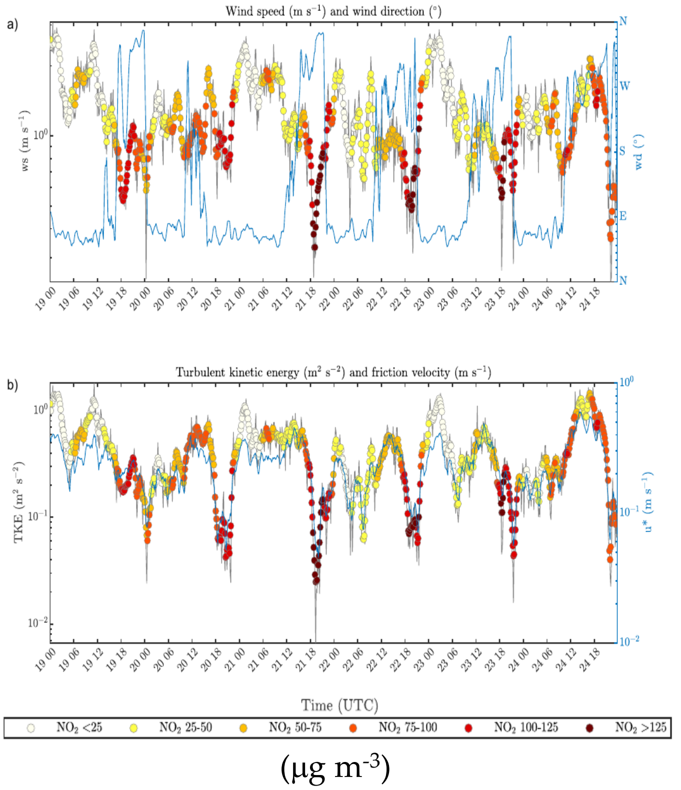


***Figure 2.** Panels displaying how NO_2 concentration (mg m^{-3}) was highly modulated by Ws and TKE.*

It is well known that meteorology plays an important role on the concentration of pollutants in urban environments. However, the MICROMET Research Group (METCLIM-UCM) has found how the meteorology-pollutant relationship is enhanced during stable periods associated with persistent anticyclonic conditions. This happened, for example, during the period comprising from 19 to 25 February 2020 during the AIRTEC-CM Winter field campaign at ETSII. During this period, the NO_2 concentration (µg m^{-3}) was highly modulated by the micro-meteorological conditions, displaying a high sensitivity to subtle changes in the wind and turbulence developed close to the surface. Under conditions, some turbulent parameters like the turbulent kinetic energy (TKE) or the friction velocity (u*) presented higher correlations with the NO_2 concentration than the horizontal wind speed. This is because these turbulent parameters include information about the vertical velocity of the flow, which gains relative importance during stable situations associated with low winds. Besides, these stable periods are also characterized by the appearance of mesoscale winds (from NE) in Madrid (probably thermally-driven / mountain breezes) that appear around midnight, favoring the diffusion of pollutants and a quick cleaning of the air at these times (Figure 2).

Objectives and Working program

OBJECTIVE 1

It is worth remarking the comparison between the wind and turbulence values obtained during the last field campaign (Summer), displaying important differences with previous ones not only due to the different season, but to the main meteorology conditions of the periods. It is important to analyze these differences considering the daytime and nighttime periods, because they show characteristic features, which are linked to the heating of the surface by the sun. For example, the turbulent kinetic energy (TKE) values reached during the ETSII Winter 2020 field campaign were especially low during nighttime (evening transition), favoring the highest NO_2 concentration measured. On the contrary, the summer turbulence during daytime, associated with the surface heating, helped to develop thermals (sensible heat, SH) that enhanced the mixing and caused the lowest NO_2 concentration (Figure 3).

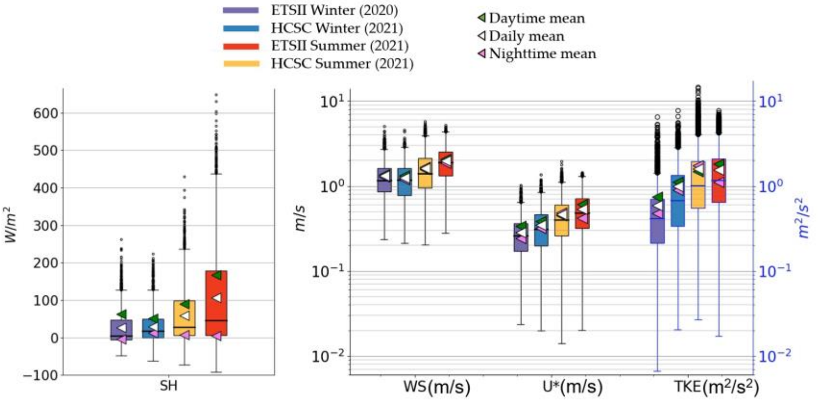


***Figure 3**. Wind and turbulence by seasons and daytime/nightime.*

1.2 Bacteria and fungi measurements

Globally, the analyses of biological particles by DNA sequencing (bacteria and fungi) showed a similar composition indoor and outdoor, so the composition indoor followed the seasonal tendencies observed outdoor (Figure 4). Moreover, no significant effect on the bioaerosols composition indoor was observed when the window was open for 2 hours during the sampling.

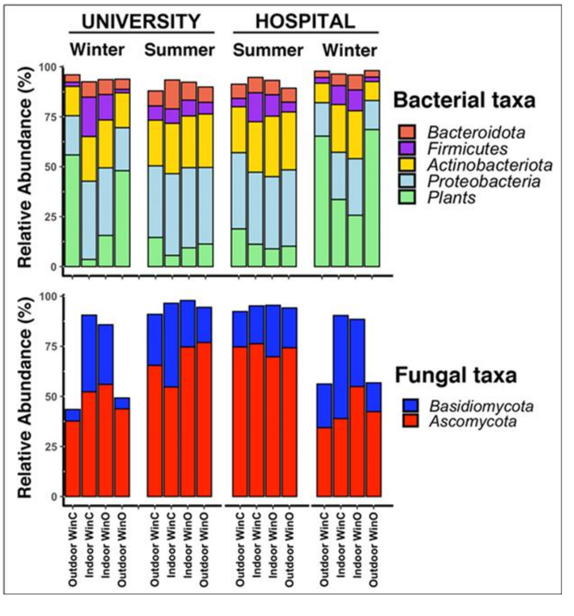


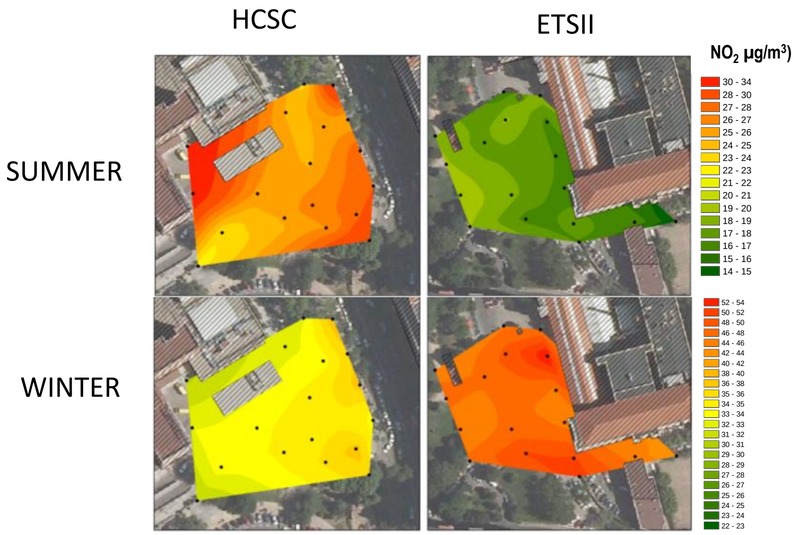
***Figure 4.** Bioaerosols composition across the different campaigns. The relative abundances of the main taxa found during bacterial and fungal analyses (top and bottom panels, respectively). WinC: samples collected with the window closed; WinO: samples collected with the window open.*

Objectives and Working program

OBJECTIVE 1

1.3 NO_2 measurements

The dots reflect the position of the passive tube samplers used for NO_2 weekly-averaged measurement for all the four campaigns carried out during the Project. The Figure 5 shows the averaged NO_2 concentrations obtained by site and season:



The NO_2 concentration was higher in summer at the HCSC, whereas the opposite occurred at the ETSII. This can be easily explained with the wind intensity and direction: during the mentioned campaigns, the synoptic conditions were characterized by anticyclonic stability with low wind and turbulence, whereas the opposite occurred during the campaigns with lower concentrations, as seen in Figure 5. Local turbulence plays a critical role due to the turbulence produced by buildings (wake) depending on wind direction.

***Figure 5**. Averaged NO_2 concentration fields from passive samplers at the four campaigns.*

The indoor/outdoor NO_2 concentration differences were assessed by means of passive samplers inside and outside the windows of the buildings at different heights (floors) as well as. The results showed that the wind intensity played an important role regarding inside-outside (I/O) percentual differences, softening the gradients when wind speed was high (Table 1), where measurements from Thermo Scientific 42i-TL/42i are also shown for comparison.

***Table 1**. NO_2 concentrations inside and outside the buildings and average I/O ratios during the campaigns from PDTs. Measurements from Thermo Scientific 42i-TL/42i are also shown for comparison.*

Campaign	Indoor PDT (µg/m³)	Indoor 42i-TL (µg/m³)	Outdoor PDT (µg/m³)	Outdoor 42i-TL (µg/m³)	Ratio I/O PDT	Ratio I/O 42i-TL	Strong wind
ETSII Winter 2020	36.5	50.6	42.7	49.0	0.85	1.03	NO
ETSII Summer 2021	19.7	19.2	16.7	16.9	1.18	1.10	YES
HSCS Summer 2020	23.8	22.2	25.2	23.8	0.81	1.01	NO
HSCS Summer 2020	30.5	25.7	28.5	33.4	1.07	0.94	YES

Objectives and Working program

OBJECTIVE 1

1.4 Additional measuring campaigns

1.4.1 Bacteria and fungi measurements: effect of dust intrusions

Windblown dust from Sahara desert frequently affects the Iberian Peninsula. Mineral particles can carry biological entities associated as bacteria and fungi. Four dust events affecting the Madrid Region during 2017 are being analyzed to study the effect on the biological components in the urban environment across different seasons.

Air samples before and during the dust influx were collected and the bioaerosols were characterized by DNA sequencing (Figure 6). Complemented by meteorological and pollution data, we will examine the changes caused by this atmospheric phenomenon.

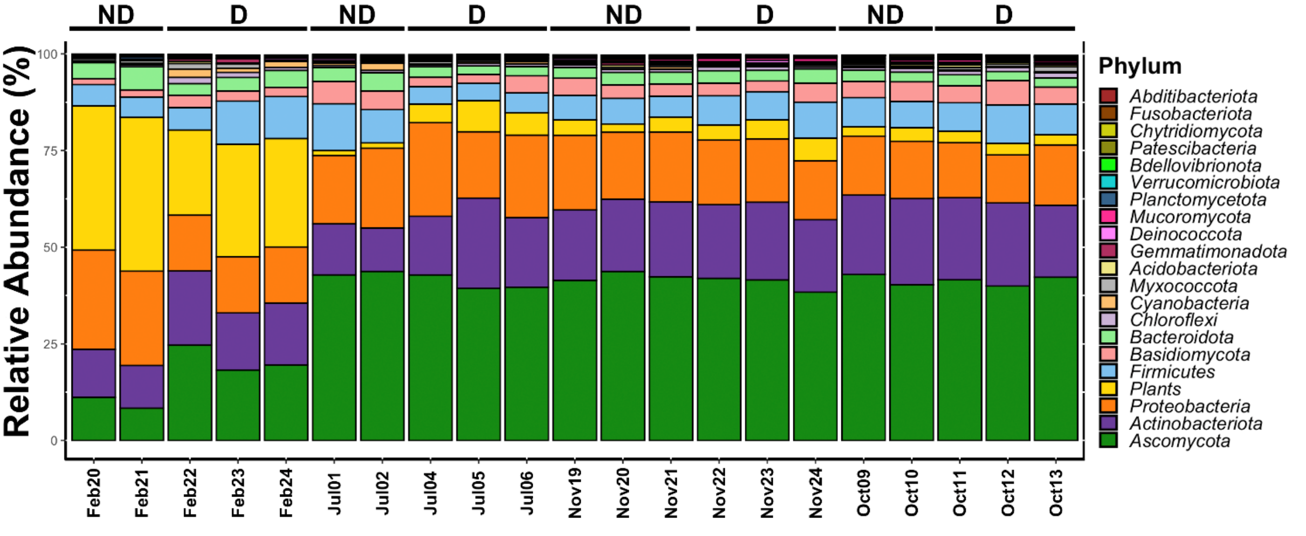


Figure 6. *Biological composition of the air particles collected prior ("ND") and during ("D") the Saharan dust events*

1.4.2 $PM_{2.5}$ and PM_{10} indoor/outdoor measurements

During the last year, the results obtained in the different experimental campaigns and checking the instruments used in the different sites during the campaigns have been analyzed. Additionally, these instruments are tested and calibrated at the CIEMAT – METALAB facilities when it is required to prepare the next campaigns.

Among the participating instruments in these campaigns are the Condensation Particle Counters (CPCs), used to measure particle number concentrations. One of them has participated in several international intercomparison campaigns performed in Leipzig, Paris and Athens. These campaigns were performed in real-world conditions, showing an important influence of the atmospheric temperature in the measurement for the CPC Magic. The microaethalometers also used to measure eBC in AIRTEC have participated in these international campaigns obtaining very good results. The instruments measuring pollutant gases (NOx, O_3) have been checked by using gas bottles with standard concentrations and GPT reaction. Very good responses were obtained for both kinds of instruments during their calibrations.

The results obtained in the different experimental campaigns carried out at two different locations have been also analyzed: a faculty and a hospital building. Ambient and indoor air pollutant (i.e. PM_{10}, $PM_{2.5}$, PM_1, ultrafine particle number concentration (PNC) and equivalent Black Carbon (eBC) concentrations were studied during specific meteorological scenarios and experiments especially designed to document outdoor/indoor interchange.

Objectives and Working program

OBJECTIVE 1

The microaethalometers were also used to measure BC in AIRTEC have participated in these international campaigns obtaining very good results. The instruments measuring pollutant gases (NOx, O_3) have been checked by using gas bottles with standard concentrations and GPT reaction. Very good responses were obtained for both kinds of instruments during their calibrations. The results obtained in the different experimental campaigns carried out at two different locations have been also analyzed: a faculty and a hospital building. Ambient and indoor air pollutant (i.e. PM_{10}, $PM_{2.5}$, PM_1, ultrafine particle number concentration (PNC) and Black Carbon (BC) concentrations were studied during specific meteorological scenarios and experiments especially designed to document outdoor/indoor interchange. Indoor/outdoor variations observed in these campaigns were associated with outdoor concentrations, which depend on sources and meteorology, but also with the activity inside. Outdoor concentrations were mainly influenced by traffic emissions, being typically several times higher than indoors. Meteorology also influenced the outdoor concentrations, being higher during winter than during summer. In the absence of occupation, the temporal evolution of air pollution showed that the indoor pollutants behaved similarly, but with delay, to outdoor ones, especially for PNC and BC produced mainly by road traffic. Room occupancy clearly affects indoor concentrations. Air particle resuspension was induced by walking inside, increasing the concentration of larger particles (PM_{10} and $PM_{2.5}$). Oppositely, open windows lead to an increase of traffic-origin pollutants (PNC, BC and gases such as NO_x) to approximately equal concentrations than outdoor. An example of the results found for PM_{10} and $PM_{2.5}$ during these campaigns can be seen in figure 7.

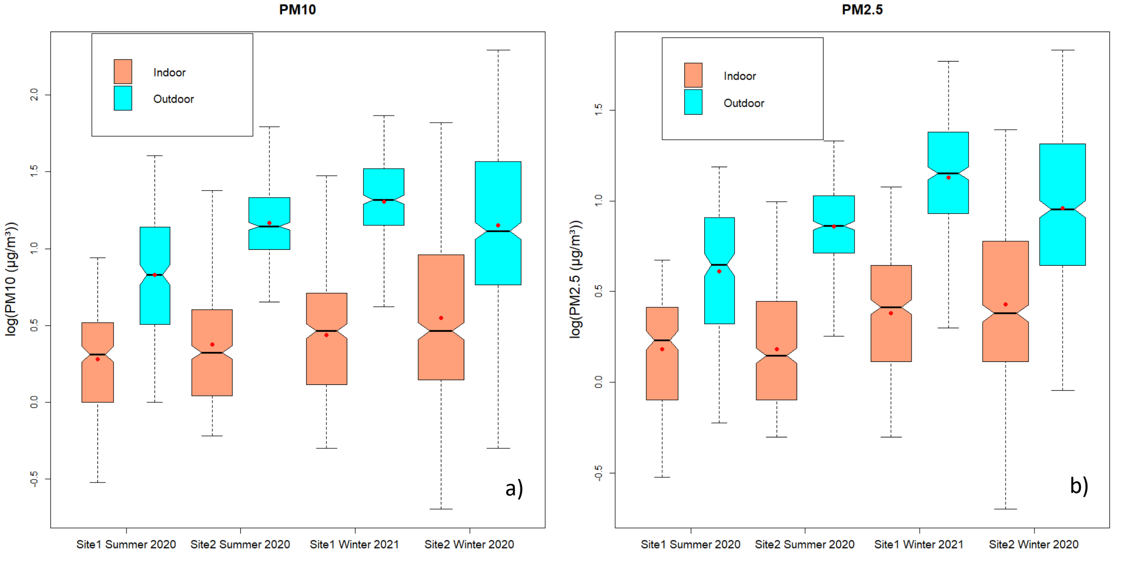


Figure 7. *Box-and-whisker plots of PM_{10} and $PM_{2.5}$ concentrations for indoor and outdoor measurements during the four campaigns a) two in the faculty building, ETSII, and b) two in the hospital building, measured under different meteorological scenarios.*

These studies are particularly important because the knowledge of indoor air quality is critical for controlling or eliminating indoor sources, as well as for minimizing contributions from outdoor sources, especially in sensitive buildings. Thus, the main findings obtained during these campaigns will be presented in two articles: one of which will be focused on indoor air quality at the faculty building and the other at the hospital.

Objectives and Working program

OBJECTIVE 1

1.4.3 Impact of urbanization on tree leaf phenology

Tree phenology in Madrid might shift in response to urbanization intensity because of the urban heat island effect in cities due to the great proportion of built-up area and the intensification of anthropogenic activities. We are using Yearly Vegetation Phenology and Productivity Indices from the Copernicus Land Monitoring Service for the period 2017-2020 to understand whether they are correlated to urbanization intensity. We have seen a moderate increase in the length of the growing season (LES) of both evergreen and deciduous trees in Madrid in response to urbanization (Figure 1). As plants play a crucial role in terrestrial ecosystems, these effects may have important consequences on ecosystems. The goal is to explore whether this is related to shifts in the flowering phenology of species with high allergenic potential. The graph below shows the length of the growing season (LES) and land surface temperature (LST) in highly, medium and low urbanized areas (percentage of built-up area < 33%, >33% and <66%, and >66%, respectively) for evergreen and deciduous trees for the period 2017-2020. LST corresponds to spring-winter yearly averages and were obtained from MODIS/Terra LST Night (MOD11A2) dataset. The differences between classes are statistically significant for all years which demonstrates the robustness of the results due to the large number of pixels analysed. However, the intensity of the difference in the length of the growing season between urbanised classes varies from year to year.

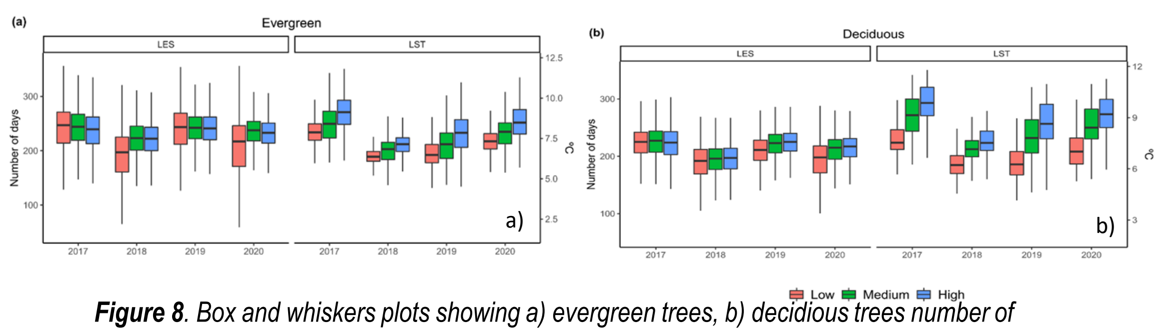


***Figure 8**. Box and whiskers plots showing a) evergreen trees, b) decidious trees number of growing days.*

1.4.4 Air Quality Data in Action: Operation Healthy Air in Western Europe.

In the winter of 2021, Earthwatch Institute in collaboration with the UPM, supported the installation of air quality sensors in 136 locations across four cities in Western Europe (Figure 9). This novel study, supported by Moody's Foundation, sought to fill critical gaps regarding exposure to volatile organic compounds in urban areas. The Understanding Your Air Quality program covered how air quality is measured, the sources of air pollution, the impacts of pollution on human health, and environmental justice—the ways in which ones' socioeconomic status correlate to disproportionate levels of environmental harm. Using high resolution mass spectrometry to identify pollution sources through the chemical signatures found on each sampler. This generated valuable data to better understand local- and individual-level exposures (https://bit.ly/OHA_EuropeDashboard).

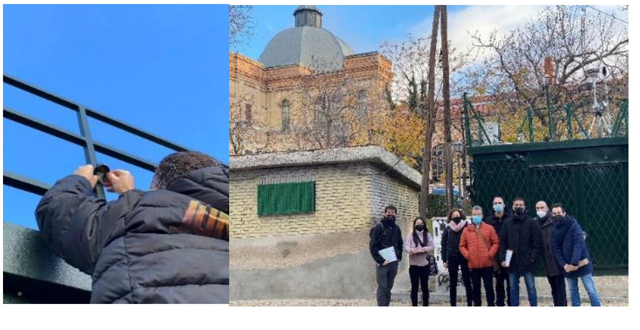


***Figure 9**. Deployment of Fresh Air Clips developed by Yale University in Madrid*

Objectives and Working program

OBJECTIVE 2

2.1 CFD simulations of outdoor-indoor fluxes of air pollutants

The outdoor-indoor exchange of pollutants that happens when a window of a building located in an urban environment is opened has been successfully simulated under real conditions using a CFD methodology.
The chosen urban area is the San Carlos Hospital and its surroundings, which adjoins high-rise buildings and crowded streets on the east and one of the main highways of the Madrid city on the west. The experimental campaign, which has been simulated, was carried out in a classroom on the fourth floor of the hospital during a weekday morning in February 2021, Figure 10.

The objective of this work is: to better understand the dispersion of traffic-related pollutants in urban environments, including the outdoor-indoor exchange of pollutants and indoor concentrations in buildings. It is helpful for a more accurate assessment of human exposure to air pollution.

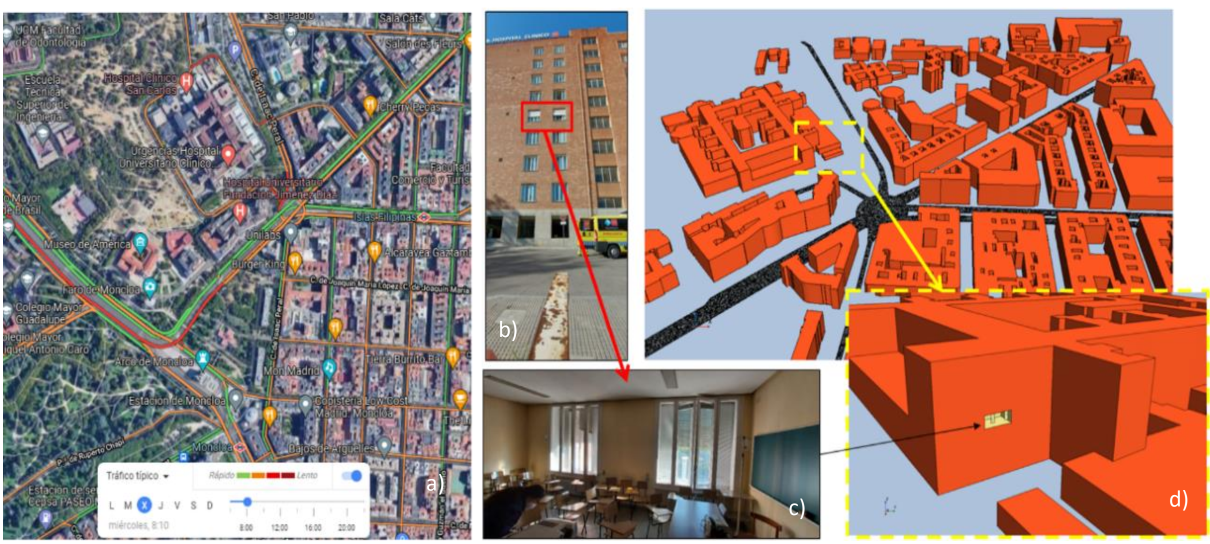


***Figure 10**. a) San Carlos Hospital and average road traffic intensity around it. b) and c) Experimental Campaign Classroom, d) CFD model in 3D (in black, traffic emissions).*

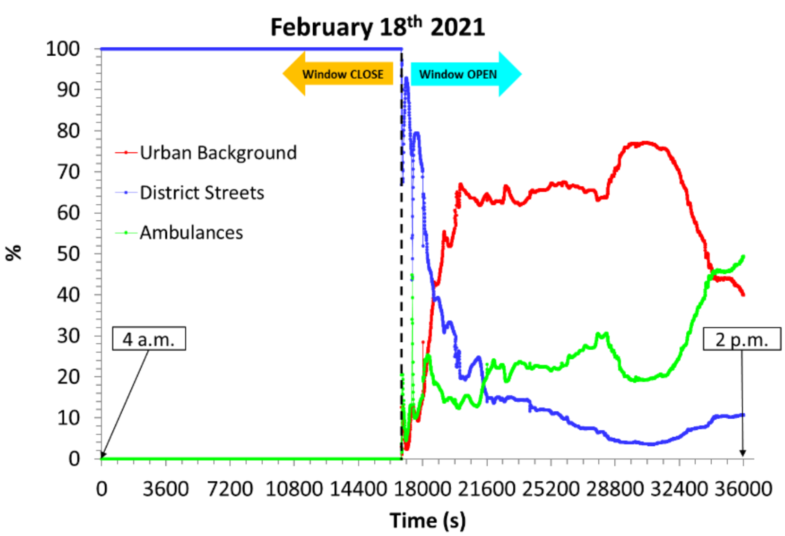


***Figure 11**. Temporal evolution of the contributions from the different emission sources to the total concentration of NOx inside the classroom.*

In this work, it has been observed that outdoor-indoor exchange is highly dependent on the outdoor meteorological conditions, particularly on wind speed and wind direction, and the distribution of NOx emissions nearby the building. For instance, according to our modelling study, idling ambulances parked around the hospital can account for up to 50% of the total indoor NOx concentration, Figure 11.

Objectives and Working program

OBJECTIVE 2

2.2 Impact of green infrastructure on traffic-related pollutant concentrations in urban areas

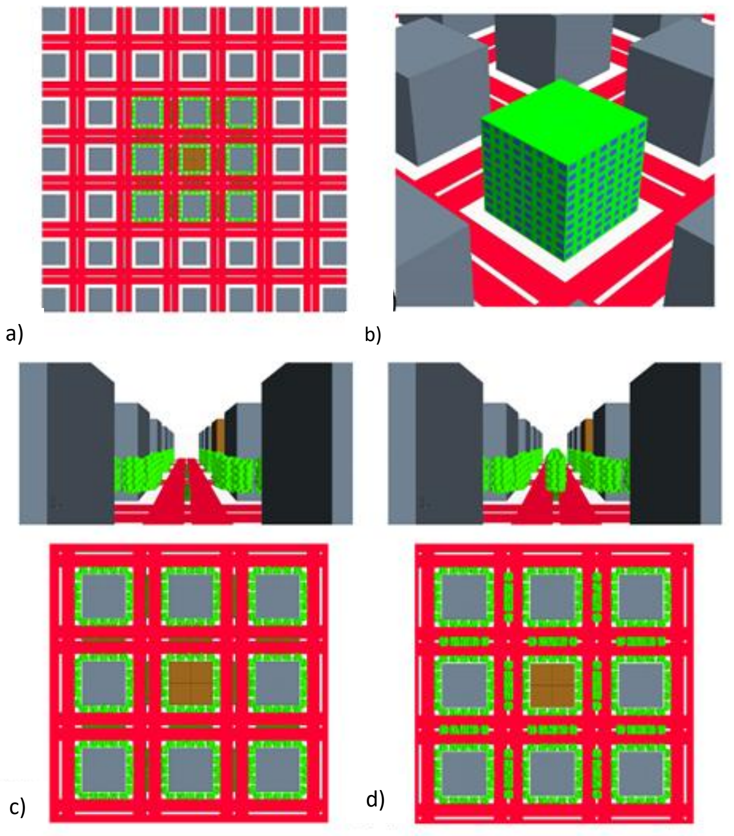


***Figure 12**. a) Array of buildings. b) Green walls and green roof location. c) Scenario with trees in the sidewalks and hedgerows in the median strip. d) Scenario with trees in the sidewalks and hedgerows and trees in the median strip.*

Also related to microscale modelling activities The effects of several green infrastructures (GI) scenarios on traffic-related pollutant concentrations at pedestrian level within an idealized urban area have been studied in collaboration with the RETOS-AIRE project. Scenarios with different configurations of street trees, hedgerows, green roof and green walls were simulated considering both aerodynamic and deposition effects through computational fluid dynamic (CFD) modelling. Figure 12 shows the idealized urban area and the location of vegetation in two different scenarios. The variation of the spatially-averaged concentrations over the neighborhood respect to the BASE (no vegetation) case for two wind directions (0º and 45º) and for several deposition velocities are shown in Figure 13. The results indicate that GI alone seems to be not effective enough generally as a measure for improving air quality. However, appropriate layout of GI elements can reduce population exposure when used for separating the population from the traffic emission. The combination of using GI with other measures such as low emission zones can be much more effective.

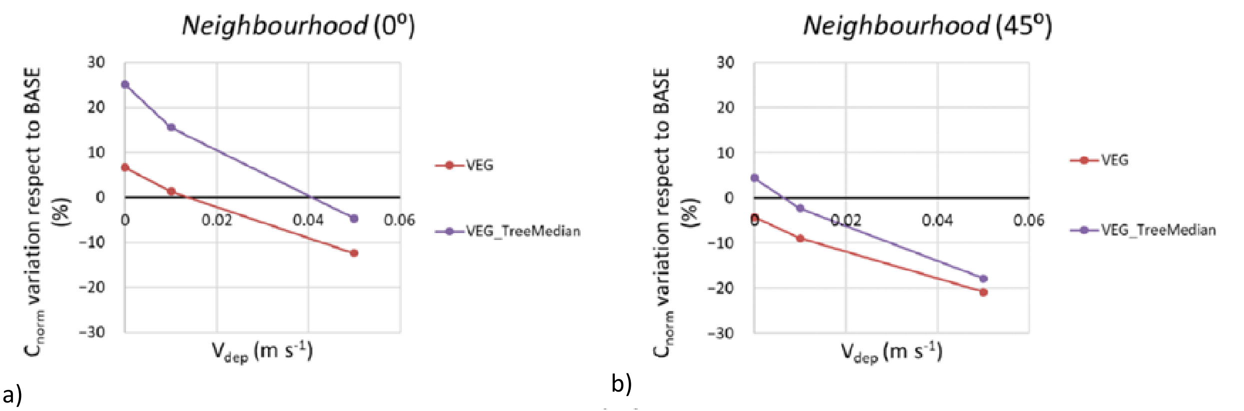


***Figure 13**. a) Variation of the spatially-averaged concentrations over the neighborhood respect to the BASE (no vegetation) case for 0º wind direction and b) 45º wind direction.*

Objectives and Working program

Measurement to improve air quality and climate change

OBJECTIVE 4

4.1 Impact of COVID-19-related restrictions on air quality

During the COVID-19 pandemic a reduction in the pollutant emissions occurred due a decrease in industrial activity and a long lockdown in Europe from early February 2020. These circumstances led to an unprecedented impact over air quality levels, specially at the largest European cities. The AIRTEC Program has studied the impact of the COVID19 lockdown over the pollutant emissions and air quality. Two high-resolution modelling domains (12 x 12 km^2 and 4 x 4 km^2) were designed for that purpose (Figure 14).

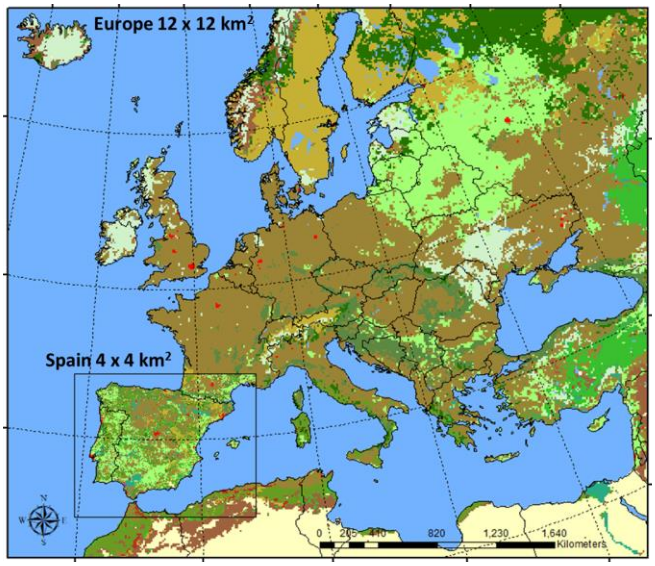
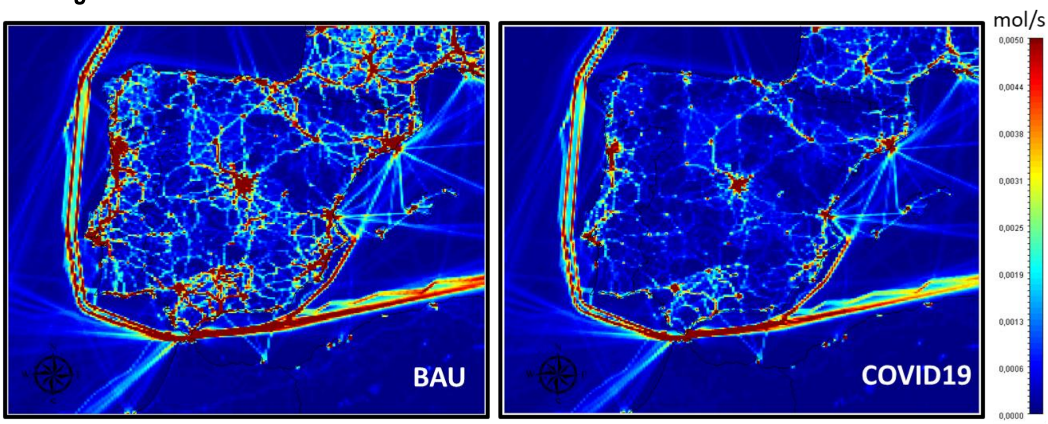


Figure 14. *Nested domains simulations.*

The meteorological simulation and emission processing for both domains and the year 2020 has been completed. The emission data have been provided by the Barcelona Supercomputing Center (BSC), for two scenarios:

- Scenario COVID19: represents what actually occurred during the pandemic.
- Scenario BAU (Business As Usual): Represents what would have happened if no pandemic had occurred.

The difference between both simulations will support the quantification of the pandemic over the air quality and the behavior assessment of the model to a dramatical reduction in the emissions, a task that will be completed in the next months.



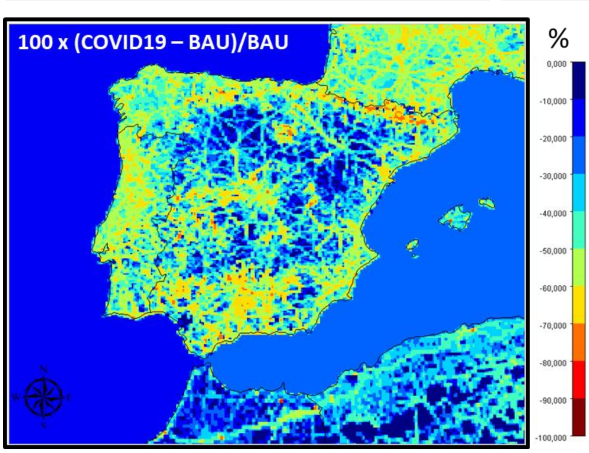


Figure 15. *Daily averaged NO_2 emissions (mole/s) and the two scenarios (BAU and COVID19).*

Average NO_2 emissions during a lookdown day are shown in Figure 15. Reductions over 30 - 60% are observed in the principal cities and rural and interurban vias.

In terms of air quality, the annual simulation is currently running with January and February already completed and it shows reductions on NO_2 levels ranging from x to y, which is in agreement with observations.

Objectives and Working program

OBJECTIVE 4

4.2 Source Apportionment

Source apportionment consists of the analysis of the contribution of each emissive source to the air quality levels produced by each specific pollutant. Several methodologies exist like the so-called single-perturbation method (SPM), in which two simulations were performed: one considering all the sectors and other where the source whose contribution is to be quantifies has been removed. The difference in the concentration is the contribution attributable to such source. Another method is the ISAM (Integrated Source Apportionment Method), that has been integrated in the chemical transport model (CMAQ-ISAM) and allows tracking emissions of any pollutant or its precursors (VOC, NOx particulate matter, typically). This method is based on two approximations; one attributes a specific secondary pollutant proportionally to all sectors reactants are originated (CMAQ v3.5.2) and the other makes the attribution to the limiting chemical specie depending on a previous sensitivity characterization (e.g. NO_X or VOC sensitive conditions for O_3 production) (CMAQ 5.0.2).

There are significative differences among methods regarding the source contributions of averaged NO_2 (Figure 16) and O_3 (Figure 17) levels. ISAM provides a clear diagnosis and thus, it is able to support the analysis of current pollution dynamics. On the other hand, SPM method retrieves information about the sensitivity of the concentration to emission reductions and therefore, it is better suited for the study of potential interventions. The three methods are not free of drawbacks, but they can support the design of new measures of emisión reductions.

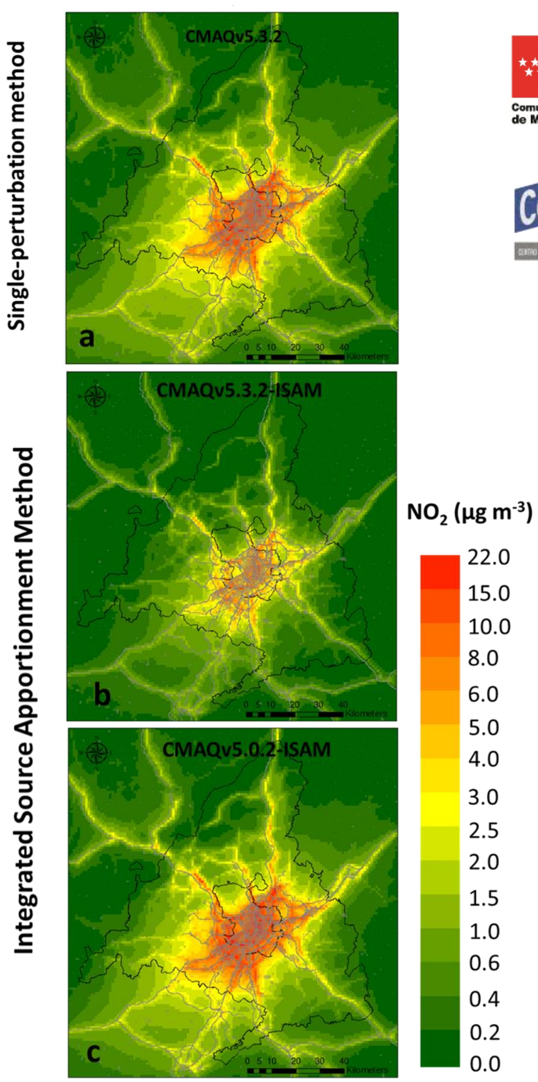


Figure 16. Summertime contribution of road traffic o average NO_2 levels.

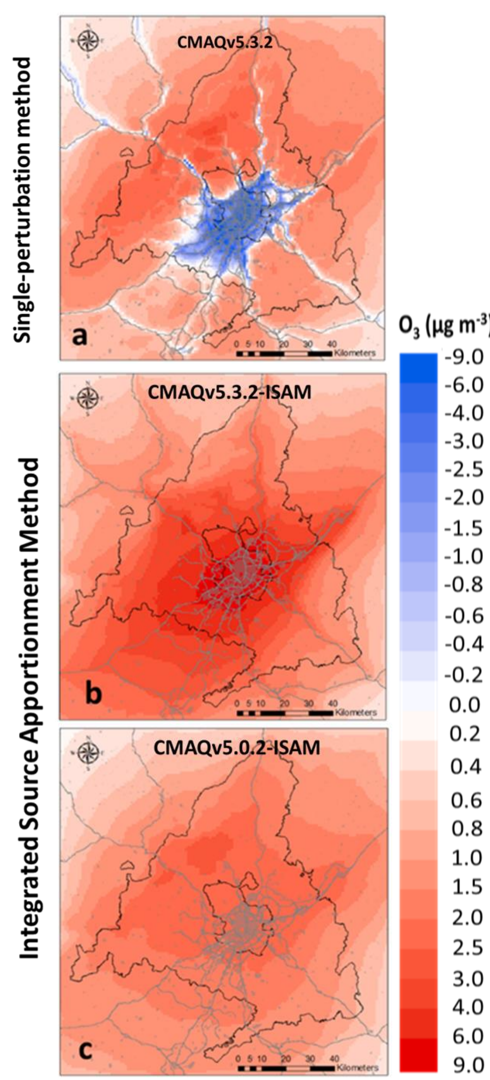


Figure 17. Summertime contribution of road traffic o average O_3 levels.

Objectives and Working program
Exposure, risks and effects on the population

OBJECTIVE 5

5.1 Pollen calendars as a dissemination tool of the pollen exposure in the Community of Madrid

The Palynological Network of the Community of Madrid (PALINOCAM) routinely samples the biological air quality of the atmosphere. Scientific and technical support is provided by the Aerobiology Research Group in the Faculty of Pharmacy (Complutense University of Madrid). The Aerobiology Group updates the information about the characterization of the aerobiological stations. Phenological (onset and length of pollen seasons) and intensity (pollen amount) parameters have been used to hierarchically classify the aerobiological stations. Different patterns of pollen emission and dispersal may be defined to identify areas with similar airborne pollen spectrum. This information is very useful for the allergic population of the Community of Madrid.

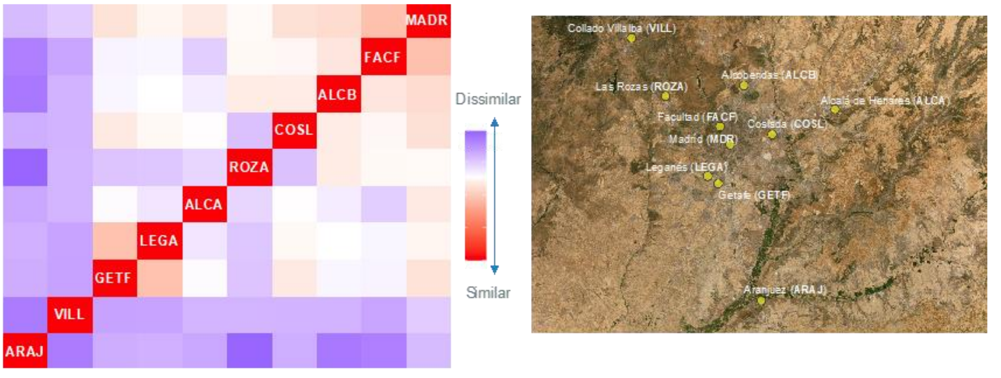


***Figure 18**. Similarity matrix of the aerobiological stations based on pollen parameters (phenology and intensity).*

A pollen calendar is a graphical interpretation of the pollen spectrum for a specific site, and it represents a dissemination tool which offers an interesting information related to public health. It clearly displays the aerobiological information for an extensive historical pollen time-series summarizing the temporal dynamics (plant phenology) and the pollen load (pollen amount) for a large number of taxa in the air. Three different aerobiological areas are defined in the Community of Madrid, and they directly correspond to different vegetation landscapes. The configuration of the pollen sources (distance and abundance) allows to define three different patterns of pollen exposure: agricultural, urbanized, agricultural, and forest areas.

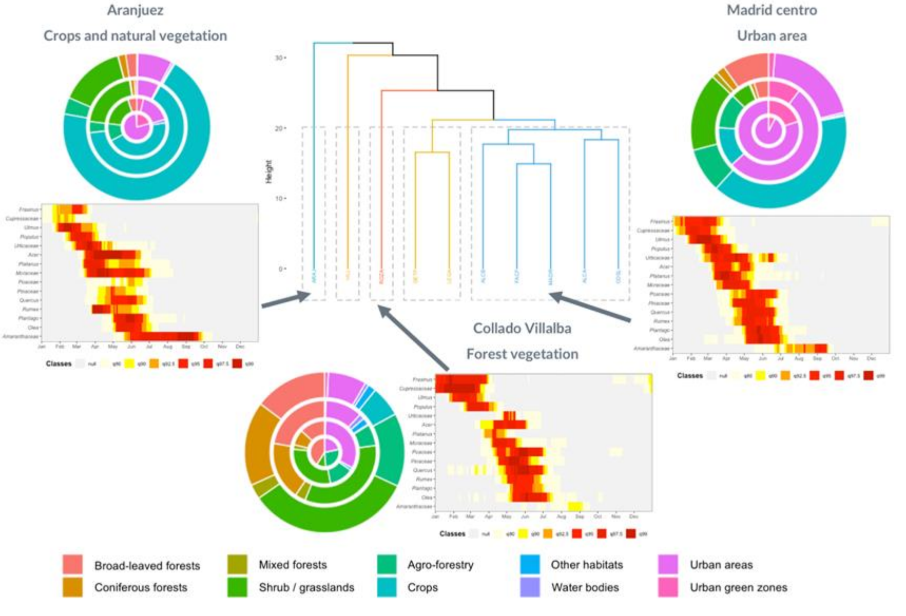


***Figure 19**. Hierarchical classification of stations and pollen calendars for three main vegetation landscapes.*

5.2 Bacteria and fungi measurements campaigns: goat farm

Some anthropogenic activities may act as emission points of biological particles contributing to the atmospheric pollution at local scale. As a representative example, we evaluated the case of a goat farm in Villa del Prado (Aldea del Fresno, Community of Madrid). The data collected are being analyzed from two different approaches: i) characterization of the biological species by DNA sequencing (in progress); ii) using the microbial counts for modelling the emissions (see preliminary results below)

Biological particles were collected using impactor-type samplers at three different points simultaneously: P1 (control), P2 (emission point) and P3 (evaluation point). Culturable bacteria and fungi were quantified in two situations: presence and absence of animals (morning and evening, respectively). Additionally, meteorological data, including wind speed and direction were acquired from a portable station near point P1. The Figure 20 shows the location of the three sampling points.

Figure 20. Aerial photograph of the farm and location of the sampling points (blue) and the portable meteorological station (red).

5.3 Inverse modelling for estimating biotic pollutant emission factors

TARINDUSTRIAL and GMCA-CIEMAT have used a stationary atmospheric dispersion model (AERMOD) and Lagrangian puff models, respectively to simulate the dispersion of biotic particles emitted from a goat farm located outskirts of Villa del Prado (West of Community of Madrid). The objective was to use both models for estimating the emission rates of bacteria and fungi derived of the goat farming using techniques of inverse modelling applied to the record data of bacteria and fungi concentration by a sampling campaign developed in January 2022 (see section 5.2).

GMCA-CIEMAT results ***(Figure 21)*** showed that some consistent emission rates were obtained, especially for the bacteria case. A sensitivity analysis has shown that the results are very depending on the initial size of each emitted puff from the farm location and the assumed stability class.

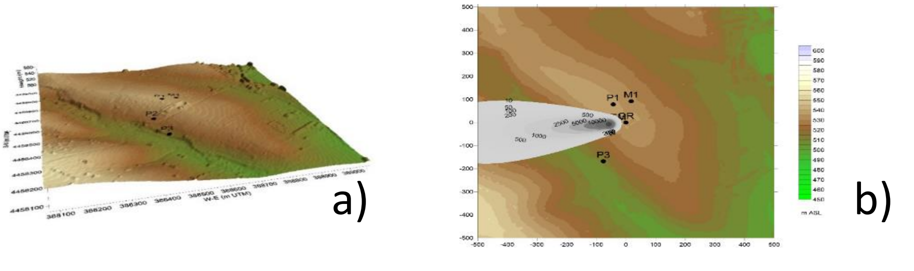


Figure 21. a) Inverse modelling applied to the farm domain and b) its results applied to the records data of bacteria and fungi.

TARINDUSTRIAL ***(Figure 22)*** found that applying the inverse emissions method from the AERMOD results, it was determined that the highest emissions occur during the presence of the goats in their pens (morning), this behavior is slightly similar to the count values obtained, however , the influence of other sources that condition the background level is presumed, with which the results would be more coherent.

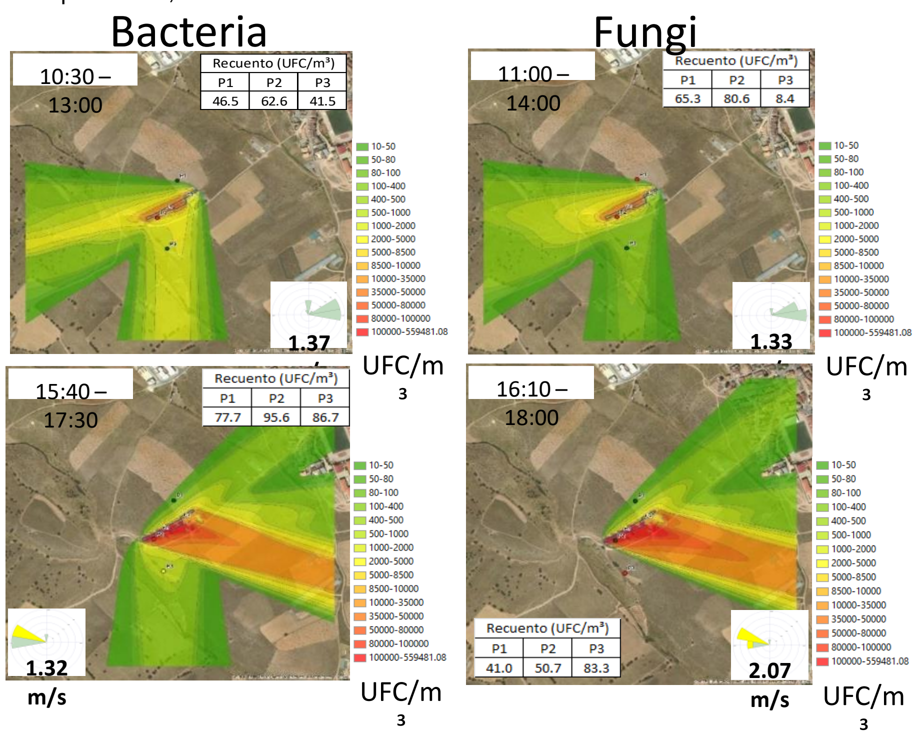


Figure 22. Bacteria and fungi counting and dispersión simulations segregated by daytime: morning and evening. Measured as UFC: Unit formator colony.

5.4 Urban Heat Island

On the other hand, a master thesis was developed in collaboration with GMCA (CIEMAT), and MICROMET groups aimed at quantifying the temperature changes associated with the urban development of the city of Madrid from 1970 to 2020. The study has been carried out with the mesoscale model Weather Research and Forecasting (WRF) and has served to observe how the urban development is linked to increases in 2-m temperature in the areas with urban development during the last decades. This is especially important during nighttime, with increases of up to 6-7 ºC in some areas with rapid urbanization, due to the urban heat island effect caused by the heat storage by the buildings and other city elements. The maps here shown correspond to the temperature difference between 2020 and 1970 for a period with the meteorological conditions from 4- 10 August 2020, attending only to the changes in urban fraction from 1970 to 2020, see Figure 23.

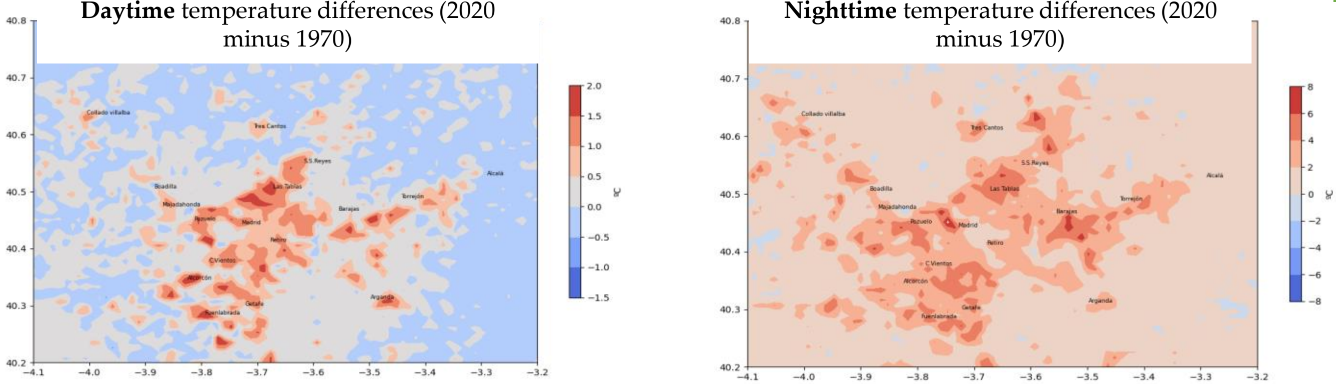


Figure 23*. Temperature changes due to urban developement.*

Objectives and Working program: Evaluation in a Climate change

OBJECTIVE 6

6.1 Meteorology-normalized method to estimate the true air pollution reduction during the COVID-lockdown period

Two machine learning algorithms (LigthGBM and XGBoost) were fitted to the past data of air quality using meteorological variables as inputs. This way we obtained a meteorological-normalized prediction when applying the models to the COVID lockdown period, which allowed us to see the true variations. Figure 24 shows the application of such models to the AQD data by pollutant and type of Station. The above 50% generalized reduction in NO_2 is clearly visible in all the AQSs. The O_3 showed a slight decrease in traffic and background AQSs but a soft increase in suburban AQSs, indicating complex interactions with VOCs regimes. The case of $PM_{2.5}$ is of extreme complexity because the highest contribution to its concentration is external advection.

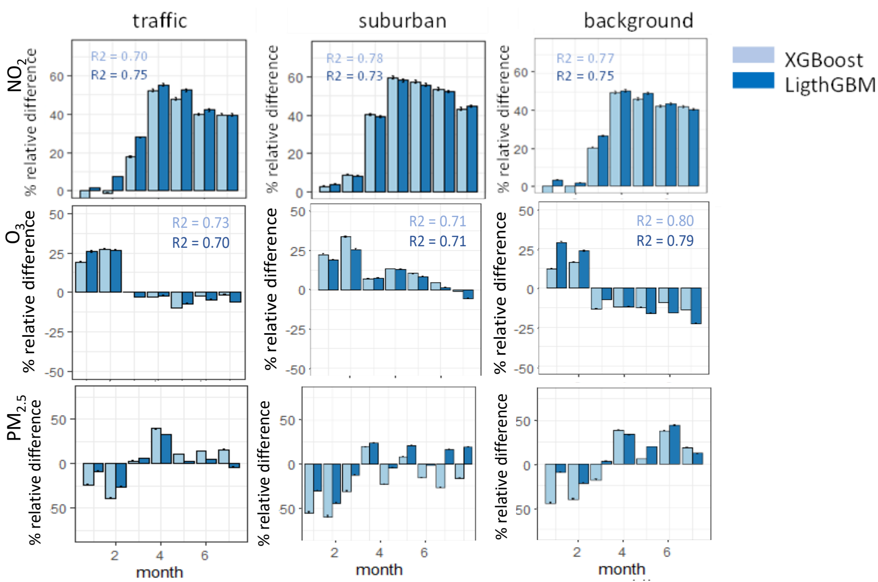


***Figure 24**. Prediction time series measurements for NO_2 and the traffic type.*

6.2 Study of the NO_2 and $PM_{2.5}$ exposures and their impact on the gut microbiota of healthy subjects

To perform this study the daily trajectories from healthy subjects over pollutions maps of the Municipality of Madrid (see example in the Figure 25-a) were intersected and the daily averaged exposure was calculated. Therefore, these trajectories should be simple and reflect the averaged daily working day routine of each subject. The exposure data was estimated using MAIAC $PM_{2.5}$ values obtained from extreme gradient boosting machine learning algorithms using several features: meteorology, emissions, AODs, population and vegetation density, land uses, etc. Also, the CMAQ $PM_{2.5}$ and NO_2 outputs were obtained. These three fields of pollutant concentration have been already used in a preliminary study of clustering to extract groups of subjects and further investigate and find their common patterns. The Figure 25-b,c shows an example of this clustering analysis (IDISCC). The study of the gut microbiota composition of healthy subjects by clustering bioinformatic techniques (b) identified two groups with different exposition to NO_2 concentrations (c).

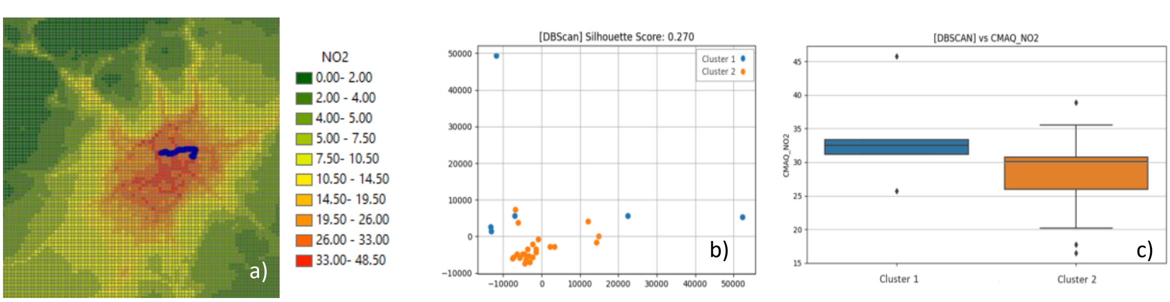


***Figure 25**. a) NO_2 ($\mu g/m^3$) calculated by CMAQ model and a trajectory; b) clustering analysis and c) bow-and-wiskers plots by cluster and NO_2.*

6.3 Annual weather simulation under the climate scenario 2018/2050

According to the object "ASSESSMENT IN A CONTEXT OF CLIMATE CHANGE", to understand the future influence of climate evolution, high-resolution regionalized simulations of global models were carried out in the Madrid Greater Region using the years 2018 (baseline) and 2050 (future) as references. For future simulations, the ds316.1 data from the NCAR (National Center for Atmospheric Research) for the year 2050 corresponding to the Representative Concentration Pathway 8.5 scenario was used, compatible with the initialization requirements of the WRF-ARW version 4.1.2 of the meteorological model (Weather Research and Forecasting - Advanced Research WRF). Some of the results obtained for Madrid Greater Region were: 42.7% reduction for cloud fraction, 81.1% reduction for non-convective precipitation, 7% reduction for planetary boundary layer, 4.5% reduction for short-wave radiation absorbed at ground and 25.1% increase for wind speed; The results obtained from the analysis of the environmental temperature are detailed below.

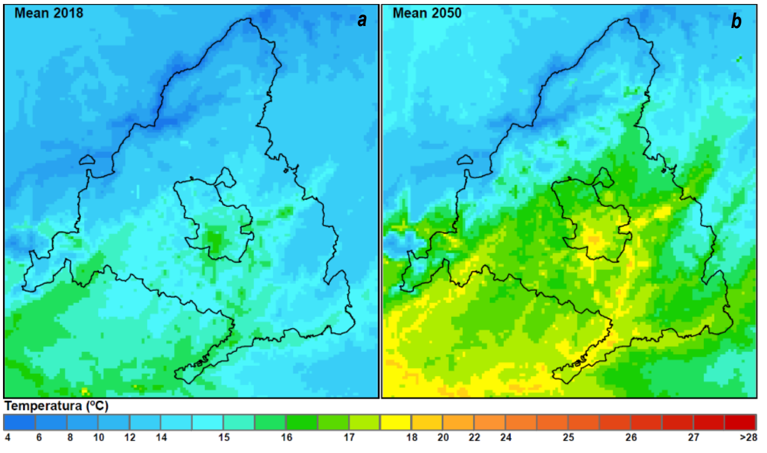


Figure 26. *Annual mean temperature a) Year 2018: Varies from 4.2 ºC to 17.6 ºC, with a mean of 13.2 ºC. b) Year 2050: Varies from 6.3 ºC to 19.3 ºC, with a mean of 15.2 ºC.*

Figure 26 shows the result of averaging the 8,760 one-hour time steps that represent the entire year, both for 2018 and 2050 scenarios.

- 2018 Scenario: Presents a mean temperature of 13.6 ºC in the Madrid Greater Region and 15.0 ºC in the Municipality of Madrid.
- 2050 Scenario: It will present an increase in the mean temperature of +1.9 ºC in the Madrid Greater Region and +2.0 ºC in the Municipality of Madrid.

Figure 27 shows the same results only for summer (months of June, July, and August).

- 2018 Scenario: Presents a mean temperature of 23.1 ºC in the Madrid Greater Region and 25.5 ºC in the Municipality of Madrid.
- 2050 Scenario: It will present an increase in the mean average temperature of +2.3 ºC in the Madrid Greater Region and +2.3 ºC in the Municipality of Madrid.

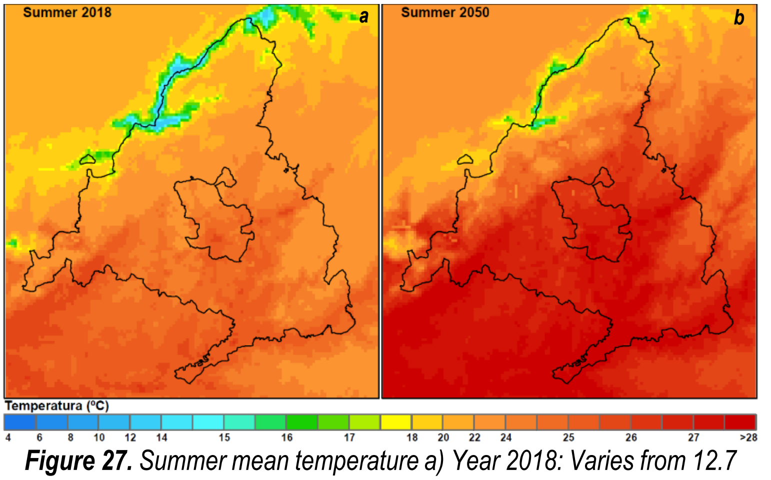


Figure 27. *Summer mean temperature a) Year 2018: Varies from 12.7 ºC to 26.2 ºC, with a mean of 22.7 ºC. b) Year 2050: Varies from 14.9 ºC to 28.6 ºC, with a mean of 24.9 ºC.*

Table 2: Summer season shows the highest values of temperature in the 2050 scenario, with a mean of 25.5 ºC and 26.7 ºC, however, the greatest variations will be reflected in the spring season with increases of +3.4 ºC and +3.3 ºC for the Madrid Greater Region and Municipality of Madrid respectively.

Table 2. *annual temperature variation 2050-2018 and in the spring and summer seasons.*

		Annual (ºC)			Summer (ºC)			Spring (ºC)
		2018	2050	+/-	2018	2050	+/-	+/-
Madrid greater region	Mean	15.0	16.9	+1.9	23.1	25.5	+2.3	**+3.4**
	Max.	16.4	18.8	+2.4	26.1	28.6	+2.5	**+4.3**
Municipality of Madrid	Mean	13.6	15.6	+2.0	24.4	26.7	+2.3	**+3.3**
	Max.	16.4	18.1	+1.7	25.7	27.8	+2.1	**+3.5**

Dissemination

Journal papers 2021-2022

- Martilli A., Sanchez B., Rasilla D., Pappaccogli D., Allende F., Martin F., Román-Cascón C., Yagüe C., Fernández F. Simulating the pollutant dispersion during persistent Wintertime Thermal Inversions over urban areas. The case of Madrid. Atmospheric Research, volume 270, 2022, 106058. https://doi.org/10.1016/j.atmosres.2022.106058
- Santiago J.L., Rivas E., R. Buccolieri R., Martilli A., Vivanco M. G., Borge R., Gatto E., Martín 2022. Indoor-outdoor pollutant concentration modelling: a comprehensive urban air quality and exposure assessment. Air Quality, Atmosphere & Health, 1-26. https://doi.org/10.1007/s11869-022-01204-0
- Rivas E., Santiago J. L., Martín F., Martilli A. Impact of natural ventilation on exposure to SARS-CoV 2 in indoor/semi indoor terraces using CO2 concentrations as a proxy. Journal of Building Engineering 46, 103725. https://doi.org/10.1016/j.jobe.2021.103725
- Santiago J.L., Rivas E., Sanchez B., Buccolieri R., Esposito A., Martilli A., Vivanco MG., Martín F, 2022. Impact of Different Combinations of Green Infrastructure Elements on Traffic-Related Pollutant Concentrations in Urban Areas. Forests, 13(8), 1195. https://doi.org/10.3390/f13081195
- Cordero JM., Borge R. Meteorological-normalized air quality improvement in the Community of Madrid during the COVID-19 lockdown due to emission changes. Frontiers in Sustainable Cities. May 2022 | Volume 4 | Article 869000 http://doi:10.3389/frsc.2022.869000
- Jung D., Lejarraga I., Borge R., de La Paz D., Cordero JM. Assessment of the Madrid region air quality zoning based on mesoscale modelling and K-means clustering. Atmospheric Environment, Volume 287, 15 October 2022,119258 https://doi.org/10.1016/j.atmosenv.2022.119258
- Quaassdorff Ch., Smit R., Borge R., Hausberger S. Comparison of microscale traffic emission models for urban networks Environmental Research Letters, Volume 17, Number 9. 7 September 2022 https://doi.org/10.1088/1748-9326/ac8b21

In Progress

- Cordero JM., Li J., de la Paz D., Koutraki P., Borge R. Dealing with the difficulties of using AOD to estimate the $PM_{2.5}$ concentrations at the Municipality of Madrid.
- De la Paz D., R. Borge R., Golam Sarwar G., Cordero JM. Análisis de contribución de fuentes en la formación de Ozone troposférico durante un episodio de alta contaminación en Madrid (Spain).
- Román-Cascón C., Yagüe C., Borge R., Ortiz P., Serrano E., Sastre M., Maqueda G., Sánchez, B., Artiñano B., Gómez-Moreno F.J., Diaz-Ramiro E., Alonso E., Fernández J., Martilli A., Cordero J.M., Narros A., García A.M., Núñez A. Wind and turbulence relationship with NO2 in urban environment: a multi-scale observational analysis.
- De la Paz D., Cordero JM., Borge R., Sarwar G. Apportionment analysis in tropospheric ozone formation during a high concentration episode in Madrid.
- J.M. Cordero J.M., Li2 J., de la Paz D., Koutrakis P., Borge R. A two-stage algorithm to estimate ground-level PM2.5 concentration levels in Madrid, Spain) from AOD satellite data and surface proxies.
- J.M. Cordero, A. Narros, R. Borge, Andrés Núñez, Ana M. García, E. Díaz-Ramiro, E. Alonso-Blanco, J. Fernández, F.J. Gómez-Moreno, B. Artíñaño, C. Román-Cascón, M. Sastre, G. Maqueda, E. Serrano, C. Yagüe. Four extensive air quality measuring campaigns at two public places in the City of Madrid (Spain)
- Galán Díaz J., Gutiérrez-Bustillo AM., Rojo J. Influence of urbanization on the phenology of evergreen and deciduous trees in Madrid (Spain).
- Núñez A., García A.M. The aerobiome in a hospital environment: characterization, seasonal tendencies and the effect of window opening ventilation.
- Study of a goat farm as an emission source of bioaerosols.
- Influence of the Sahara dust storms on the urban aerobiome in the Iberian Peninsula.
- Real-time measurements of Indoor–Outdoor exchange of gaseous and particulate atmospheric pollutants in an urban area.
- Indoor/outdoor particulate matter and related pollutants in a sensitive building of Madrid (Spain).

Dissemination

Conferences 2022

- Borge R., de la Paz D., Cordero JM., Sarwar G., Napelenok S.: Comparison of Source Apportionment Methods to attribute summer tropospheric O3 and NO2 levels in Madrid (Spain). 21st International Conference on Harmonization within Atmospheric Dispersion Modelling for Regulatory Purposes 27-30 September 2022, Aveiro, Portugal.
- Yagüe C., Román-Cascón C., Ortiz P., Sastre M., Maqueda G., Serrano E., Artíñano B., Gómez-Moreno F. J., Díaz-Ramiro E., Alonso E., Fernández J., Borge R., Narros A., Cordero, J. M., García A. M., and Núñez A.: How do the local meteorology and turbulence influence the nitrogen dioxide concentration in Madrid, EGU General Assembly 2022, Vienna, Austria, 23–27 May 2022, EGU22-10292, https://doi.org/10.5194/egusphere-egu22-10292 , 2022.
- Román-Cascón C., Yagüe C., Ortiz P., Sastre M., Maqueda G., Serrano E., Artiñano B., Gómez-Moreno F. J., Díaz-Ramiro E., Alonso E., Fernández J., Borge R., Narros A., Cordero J. M., García A. M., and Núñez A.: Observational analysis of the wind speed and turbulence relationship with NO2 concentration, EMS Annual Meeting 2022, Bonn, Germany, 5–9 Sep 2022, EMS2022-194, https://doi.org/10.5194/ems2022-194 , 2022.
- Rivas E., Santiago JL., Martín F., Martilli A., Díaz E., Gómez FJ., Artiñano B., Román-Cascón C., Yagüe C., de la Paz D., Borge R., 2022. Infiltration of NOx from road traffic into buildings by natural ventilation: a case study. 21st International Conference on Harmonization within Atmospheric Dispersion Modelling for Regulatory Purposes 27-30 September 2022, Aveiro, Portugal.
- Santiago JL., Rivas E., Sanchez B., Buccolieri R., Carlo OS., Martilli A., Vivanco MG., Martín F., 2022. Impact of green infrastructure on traffic-related pollutant concentration in high-rise urban areas. 21st International Conference on Harmonization within Atmospheric Dispersion Modelling for Regulatory Purposes 27-30 September 2022, Aveiro, Portugal.
- Santiago JL., Rivas E., Sanchez B., Buccolieri R., Martilli A., Vivanco MG., Esposito A., Martín F., 2022. Ranking of various single and combinations of local air pollution mitigation measures in an urban environment. 21st International Conference on Harmonization within Atmospheric Dispersion Modelling for Regulatory Purposes 27-30 September 2022, Aveiro, Portugal.

Other dissemination activities

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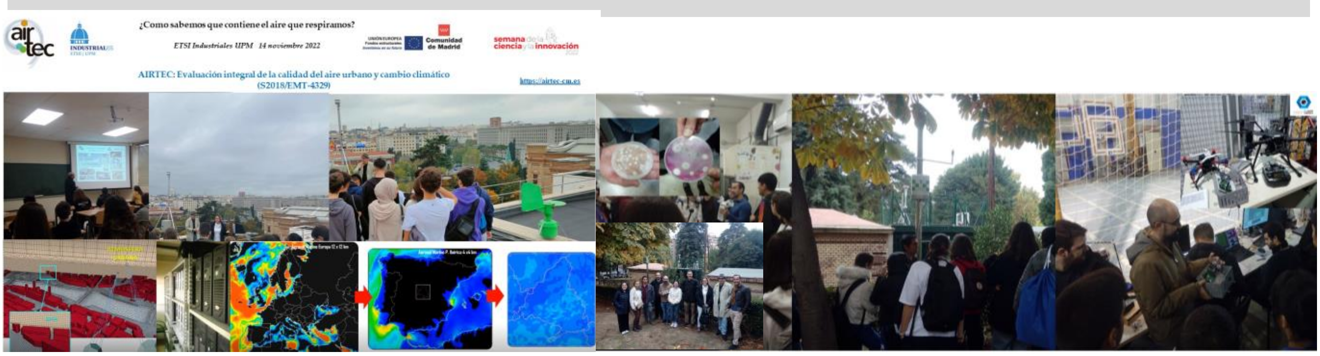

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