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D5.3 Mid-term Report on the CoE's scientific leadership in regional environmental observations

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1. Introduction 5

2. Embedding high quality long-term atmospheric observations in international networks (Task 5.3) 6

2.1. Gradual transfer of scientific leadership to the newly recruited/trained research staff of the Environmental Observations Department (Task 5.3.a) 6

2.1.1 International Dual Degree Ph.D. 7

2.1.2. Scientific training of CoE staff and students 8

2.1.3 Transfer of knowledge through Erasmus+ mobility 8

2.2. Supporting integration into EU research infrastructures and international networks by the advanced partners (Task 5.3.b). 9

2.2.1. ACTRIS (The Aerosol, Clouds and Trace Gases Research Infrastructure) 9

2.2.1.1. ACTRIS labelling process 9

2.2.1.2. Services provided by ACTRIS and participated by the CoE 10

2.2.1.3. TNA access to CAO facilities 10

2.2.1.4 Future plans for ACTRIS 10

2.2.2 ICOS (Integrated Carbon Observation System) 11

2.2.2.1 Building the station – start GHG measurements 11

2.2.2.2 Future plans for ICOS 11

2.2.3 Long-Term Ecosystem Research Infrastructure (eLTER) 11

2.2.4 The Total Carbon Column Observing Network (TCCON) 12

2.2.4.1 TCCON Observations 12

2.2.4.2 NDACC upgrade 13

2.2.4.3 TCCON future plans 13

2.2.5 AERONET and other remote sensing networks 13

2.2.6 European Monitoring and Evaluation Program (EMEP) 14

2.2.7 WMO-GAW (Global Atmosphere Watch) 14

3. Development in regional scientific capacities regarding the atmospheric environment (Task 5.4) 15

3.1. Development of scientific capacities with regional partners 15

3.1.1. EMME-CARE annual online workshop 15

3.1.2 EMME-CARE autumn school 15

3.1.3 Active MoUs and collaboration agreements (CA) with regional partners 16

3.1.4 Publication list with regional scientific collaborators on Environmental Observations (as per WP5) 17

3.2. Establishment of regional observation networks 18

3.2.1 Construction of Air Quality laboratory in Cairo (Egypt) 18

3.2.2 Intensive field observations in Beirut (Lebanon) 19

3.2.3. Intensive field observations in Cairo (Egypt) 20

3.2.4. Intensive field observations in Saudi Arabia 21

3.2.5. Fine aerosols sources and their gas precursors in Cairo, Egypt (POLCAIR) 21

3.2.6. The Atmospheric Research Expedition to Abu Dhabi (AREAD) 22

3.2.7. Transport of Hydrocarbons & Ozone Formation downwind of the Arabian Gulf (THOFA) 23

3.2.8. Residential biomass burning in Ioannina (Greece) 24

3.2.9. Construction of a regional Pollen monitoring network 25

4. Future plans to expand regional coverage of observations 27

4.1. Beirut (Lebanon) Atmospheric Observations Supersite 27

4.2 Amman (SMEAR-Jordan) Atmospheric Observations Supersite 27

4.3 Cairo (Egypt) Atmospheric Observations Supersite 28

ANNEX 1 – Publication List with Regional (EMME) Partners 29

1. Introduction

The "Eastern Mediterranean Middle East – Climate and Atmosphere Research" Project (EMME- CARE, H2020 GA no.856612) provides scientific, technological, and policy solutions by establishing a world-class Center of Excellence focusing on environmental challenges. To address these objectives, the Atmosphere & Climate Division (ACD) of the Cyprus Institute (CyI) has been upgraded, its partnerships with world-renown institutes strengthened, and its status and contribution in the field's regional/global networks enhanced. The new CoE established (in January 2020) is the Climate and Atmosphere Research Center (CARE-C) of the CyI.

The Deliverable 5.3 provides a "**Mid-term update on the Centre of Excellence (CoE)'s leadership in the regional environmental observations"** concentrating in high quality long-term atmospheric observations embedded in various international networks. In the report we will summarize the status in integrating the CoE's observational capacities into EU research infrastructures and international networks, identify the activities leading to enhancements in regional scientific capacity and CoE leadership development. We will describe the gradual transfer of scientific leadership of the continuous monitoring activities to the newly recruited faculty, research and technical staff of the Environmental Observations Department (EOD). The deliverable is tightly linked to **task 5.3** and **task 5.4**.

Task 5.3. **High quality long-term atmospheric observations embedded in international networks** (Lead: UH) (M12 to M84)
The Advanced Partners will:
a. Gradually transfer the scientific leadership of the continuous monitoring activities to the newly recruited/ trained research staff of the Environmental Observations Dept. (M12-M36).
b. Support their integration into EU research infrastructures (ACTRIS, ICOS, eLTER) and international networks (GAW, BSRN, ADAGE, CTBT) (M24-M48).
Task 5.4. **Enhance regional scientific capacities on atmospheric composition** (Lead: CyI) (M36-M84)
The Environmental Experiments Department will
a. Develop regional scientific capacities regarding the atmospheric environment; establish a regional observational network connected to EU Research Infrastructure, using the CoE as a regional node for capacity building.
b. Actively engage its regional collaborators in high quality research, leveraging the EMME Professorship Programme and using the same strategy developed by the Advanced Partners

2. Embedding high quality long-term atmospheric observations in international networks (Task 5.3)

2.1. Gradual transfer of scientific leadership to the newly recruited/trained research staff of the Environmental Observations Department (Task 5.3.a)

Task 5.3.a. completed. The transfer of scientific leadership on research topics such as aerosol formation, greenhouse gases, reactive trace gases and aerosol remote sensing is completed with recruitment / training of new faculty members and technical staff in 2021 (Month 24). More information in Deliverables D5.1 (Report on the structure of the Environmental Observations Department) submitted in Month 24, Milestone MS19 (Environmental Observations Research Department established & fully operational) submitted in Month 24, as well as Deliverables D2.2, D2.3, and D.2.6 which refer to the first, second, and third reports in updated HR recruitments

Briefly:

- **Tuija Jokinen** (Female, Assistant Professor, recruited 08/2021): Aerosol formation group lead by Asst. prof. Tuija Jokinen was established in May 2023 with the support of ERC-2022-STGERC-BAE-Project:101076311, awarded to her in the 2022 call. Currently, the group consist of 1 Ph.D. student (cotutelle agreement for dual Ph.D. with UHEL) and in October 2023 2 more Ph.D. students and one Associate Research Scientist will be employed to study the role of bases in aerosol formation. The first nanoparticle and complimentary aerosol precursor molecule and cluster measurements were carried out at the CAO-Agia Marina Xyliatou (AMX) station in the spring of 2018 and are carried on until now. The newly purchased (from EMME-CARE funds) MION-APi-TOF has been installed to AMX in May 2023 and will be producing the first aerosol formation chemistry observations in the region soon.
- **Asst. prof. Efstratios Bourtsoukidis** (Male, Assistant Professor, recruited 08/2021): After seven years at an advanced partner Institute (MPIC), Assist. Prof. E. Boutsoukidis was recruited to develop research on atmospheric reactive trace gases. Within his role as a faculty member, he has expanded the main pollutant observations (i.e., NO, NO2, SO2, O3) to include a comprehensive suite of Volatile Organic Compounds (VOCs) using a state-of-the-art system (PTR-ToF-MS) that was acquired with EMME-CARE funds. This cutting-edge device, the first of its kind in Cyprus, is capable of real-time monitoring of hundreds of VOCs. It has been deployed at CAO stations and in EMME regional campaigns, providing crucial data on regional trace gas sources and contributing to a deeper understanding of atmospheric chemistry processes. Using his extensive past experience, he has successfully led three field campaigns and is currently in the process of establishing the Mobile Laboratory of CARE-C.
- **Franco Marenco** (Male, Associate Professor, recruited 05/2021): remote sensing observations from UK Met Office- Assoc. Prof. Franco Marenco has taken a lead to develop the remote sensing measurements at CAO stations. He has extended the network of sunphotometers and lidars on the island of Cyprus with his group that currently includes a Ph.D. student Alkistis Pappetta.
- **Jean-Daniel Paris** (Male, Research Affiliate, Advanced Partner): Dr. Paris contributes expertise in greenhouse gas measurements. Measurements from mobile platforms have adapted on cars and drones (joint CEA-CyI Ph.D. of Yunsong Liu), while ensuring long term interoperability and WMO-scale traceability. These GHG measurements have also been embarked on ship campaigns, leading to new insight in GHG variability over the EMME region. GHG research include the use of co-emitted species such as VOCs (joint CEA-CyI Ph.D. of Emeric Germain Piaulenne). High precision fixed rooftop measurements have been collected over Nicosia benefitting from earlier experiences in France. Jean-Daniel organises GHG measurement team meetings at CARE-C. He also contributed to CyI competitiveness in national and EU projects related to ICOS and GHG measurements, as well as hydrogen measurements in industrial environment.

- **Roland Sarda-Estève** (Male, Research Affiliate, Advanced Partner): Bioaerosols – Dr. Sarda-Estève, has pioneered bioaerosol research at CEA/LSCE since 2013 with the development of a portable bioaerosol sampler (BIODOSI) and an online particulate matter analyser. In 2014, he initiated and managed the first international intercomparison campaign of online detectors of airborne biological particles (BIODETECT). Since 2015, he has led the CEA/LSCE Bioaerosols Team and integrated the French National Network of Aeroalergens (RNSA) in the CEA ACTRIS Observatory as a pilot site for atmospheric research on climate and bioaerosols. Since 2018, Roland Sarda-Estève has begun to complement these observations with atmospheric bacteria concentration and biodiversity monitoring. His recognized knowledge in gas and particles instrumentation led him to assume the responsibilities of project manager for the CBRNE research and innovation projects at CEA or EMME-CARE. During the EMME-CARE project, he will be in charge of the bioaerosol measurements in Cyprus as a mirror of Saclay. His knowledge on atmospheric sciences and instrumentations will be transferred the CAO team during this period.
- **Maria Kezoudi** (Female, Associate Research Scientist, recruited 01/08/2023): Following her Ph.D. project at UH on the calibration/validation of the Universal Cloud and Aerosol Sounding System (UCASS); an open-path Optical Particle Counter (OPC), Maria initiated a collaboration between CARE-C and UH on the use of UCASS sensors. Due to its light weight and compact size, UCASS is ideal for UAV-atmospheric measurements. UCASS units were successfully integrated on-board the fixed-wing UAVs of the USRL. She has conducted aerosol property studies within 5.5 km Above Sea Level (ASL) over Cyprus and EMME region and she studies seasonal variability of large particles, mainly dust (up to 40 μm in diameter).
- Sypros Bezantakos (Male, Associate Research Scientist, recruited 2022): Specialises in development of a test bench for characterizing the performance of miniature/portable aerosol sensors at low temperature-pressure conditions (i.e., similar to those encountered by the instruments onboard lightweight platforms) and the performance of miniature/portable gas sensors in variable environmental conditions (temperature and RH). He is also responsible for the further development of a cost-effective particulate matter monitor (optical particle counter) for mobile applications (ongoing real-life conditions testing) and an in-house, custom-made Hygroscopicity Tandem Differential Mobility Analyzer (HTDMA) system, that was deployed for measuring aerosol hygroscopicity and mixing state at CAO-AMX and Cairo (Egypt).

2.1.1 International Dual Degree Ph.D.

The CoE offers international dual degree PhD opportunities, with many of its international partners through the Cotutelle scheme. Cotutelle is a mechanism that promotes mobility among doctoral candidates while encouraging scientific cooperation between research teams in different countries. For example, current CoE PhD Student Aliki Christodoulou is doing a Dual Degree PhD with the Cyprus Institute and the IMT Lille Douai / University Lille (France) and a current Ph.D. graduate Yunsong Liu completed her dissertation as part of her Dual Degree with the Cyprus Institute and CEA / University Paris-Saclay (France) on Dec 14 2022.

The CoE has had / currently has 20 postgraduate students with Cotutelle agreements in total making up around 20% of total student population. Currently, the Ph.D. students are engaged in Joint / Dual Degrees with the following universities:

- University of Paris-Saclay, France
- IMT Lille, France
- University of Helsinki, Finland
- National and Kapodistrian University of Athens, Greece

2.1.2. Scientific training of CoE staff and students

The CoE offers variable transferrable skills courses to further educate its staff and students. **Table 1** depicts the participation of CARE-C staff and students on the transferable skills courses organized by the graduate school.

Table 1. Participated transferable skills courses by the CARE-C staff and students.

CARE-C Participant	Transferable skills course	Course period	Lectures
Tuija Jokinen	Proposal Writing for Research Grants	May-22	4 x 3 h
Aayushi Sharma	Proposal Writing for Research Grants	May-22	4 x 3 h
Thaleia Graikou	Publishing in academia: How to be a successful author and reviewer	Dec-22	4 x 3 h
Vincent Kipkemoi	Publishing in academia: How to be a successful author and reviewer	Dec-22	4 x 3 h
Rawan Fayad	Basic Introduction to Python	Mar/Apr-23	8 x 3 h
Margarita Satraki	Basic Introduction to Python	Mar/Apr-23	8 x 3 h
Constantina Rousogenous	Basic Introduction to Python	Mar/Apr-23	8 x 3 h
Mohsen Mahammadi	Basic Introduction to Python	Mar/Apr-23	8 x 3 h
Chirstos Xenofontos	Basic Introduction to Python	Mar/Apr-23	8 x 3 h
Neha Deot	Basic Introduction to Python	Mar/Apr-23	8 x 3 h
Spyros Bezentakos	Basic Introduction to Intellectual Property	May-23	4 x 3 h
Christoforos Skourides	Basic Introduction to Intellectual Property	May-23	4 x 3 h

2.1.3 Transfer of knowledge through Erasmus+ mobility

The Erasmus Programme (European Region Action Scheme for the Mobility of University Students) is a European Union (EU) student and staff exchange programme covering 34 countries in total. The Cyprus Institute was awarded ERASMUS Charter on December 11, 2013 and it was renewed on February 27, 2021. The mobility utilizing ERASMUS+ program is depicted in **Table 2**.

Table 2. CARE-C staff and student mobility in ERASMUS+.

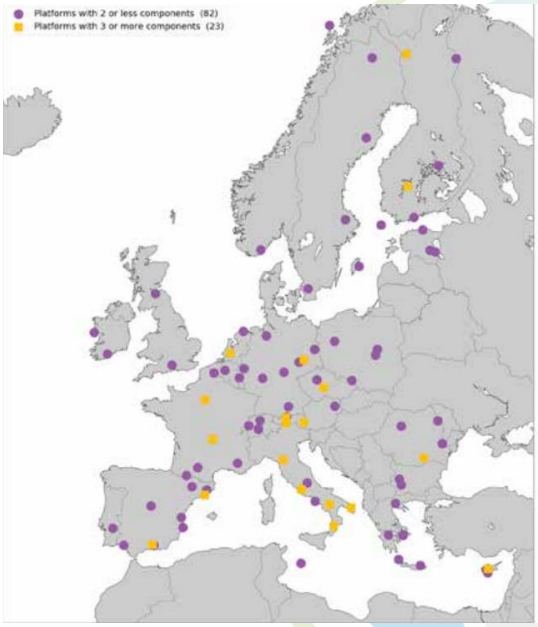
CARE-C Participant	ERASMUS+ Program	Host organization	Mobility period
Marina Manoura	Staff mobility for training	Max Planck Institute for Chemistry, Mainz, Germany	18.-20.7.2022
Pierre-Yves Quehe	Staff mobility for training	The National Observatory of Athens	16.-18.6.2022
Neha Deot	Student mobility for traineeship	University of Helsinki, Helsinki, Finland	27.2.-10.3.2023

2.2. Supporting integration into EU research infrastructures and international networks by the advanced partners (Task 5.3.b).

This Task has been initiated in M24 (Sep. 2021) and is currently extended until the end of the project since the integration into international networks is taking more than expected. The CoE currently participates in several ESFRI projects and the development in integration to those infrastructures and other national networks is reported below in details.

2.2.1. ACTRIS (The Aerosol, Clouds and Trace Gases Research Infrastructure)

The government of Cyprus is one of the 13 EU member states in the newly established ACTRIS-ERIC in 2023. The total amount due for Cyprus is 62,795€ for the year 2023. The Cyprus Government is financially committed to cover the annual membership fee from the Cyprus Government (DGEPCD) while each Research Performing Organization part of ACTRIS-Cyprus has to cover the expenses related to the participation of its National Facilities. **CARE-C is operating two (2) out of three National Facilities of ACTRIS-ERIC, namely CAO and USRL**. More information on these facilities can be found in Deliverable D4.3 (Mid-term Report on the operation of the EMME-CARE research facilities).



Overview of the pan-European ACTRIS distributed network (incl. observations performed in Cyprus by CARE-C)

2.2.1.1. ACTRIS labelling process

The CAO-AMX station applied for the ACTRIS aerosol in situ measurements labelling in the year 2022. This was done after all necessary instrumentation were purchased and installed and technical work (building inlets, drying systems and temperature control of the station) had been completed during year 2022 and early 2023. ACTRIS labelling is a multi-step process, with the first one including three sub-steps: 1a) initial acceptance, 1b) performance evaluation and 1c) approval. CAO-AMX has started the labelling process in May 2023 with a station audit and has received an evaluation report shortly after. It concluded that **CAO-AMX is ready for the initial acceptance of the labelling process and that the minimum requirements of the aerosol in-situ variables are already fulfilled**. This is the most important achievement to be noted in this mid-term report for ACTRIS.

In addition to the official aerosol in situ measurements (particle number concentration >10 nm, particle number size concentration 10-800 nm, Particle light scattering and backscattering coefficient – multiwavelength and Particle light absorption coefficient and black carbon), the CAO-AMX is equipped to report several complimentary ACTRIS aerosol in situ and remote sensing variables and reactive trace gases and condensing vapors – in situ variables. These include long term measurements of Nano

particle number concentration < 10 nm (available since 2018), Nano particle number size distribution 1-20 nm (available since 2018), Cloud Condensation nuclei number concentration (instrument purchased), mass concentration of particulate organic and elemental carbon (sampling without denuder, not fully align with ACTRIS measurement guidelines) and periodical Mass concentration of non-refractory particulate organics and inorganics. Reactive trace gas and condensing vapour measurement include VOC and NMHC observations, sulfuric acid and highly oxygenated organic measurements.

2.2.1.2. Services provided by ACTRIS and participated by the CoE

Integration to ACTRIS has been better reached with **participation to calibration and intercomparison workshops at ACTRIS topical centres**. For instance, NAIS and technical staff member participated in the first calibration workshop in May 2023 and the MION-APi-TOF participated in 2-week intercomparison workshop in February 2023.

2.2.1.3. TNA access to CAO facilities

Support in TNA access through ATMO-ACCESS to CAO-AMX and USRL has improved international collaboration within ACTRIS national facilities and European researchers and private companies and SMEs. CAO-AMX offers TNA access provided in the EU ACTRIS Research infrastructure to improve atmospheric observations coverage and CAO regional impact. Operations include collaboration with private companies (e.g. Karsa ltd, Finland), training of new users (e.g. Ph.D. students, tech staff). **Table 3** depicts the TNA access that took place throughout the ATMO-ACCESS project to CAO-AMX (https://www.atmo-access.eu/).

2.2.1.4 Future plans for ACTRIS

Before starting valid ACTRIS measurements, the CAO-AMX inlet system needs to be improved. This will be conducted in the autumn of 2023 in order to initiate the next steps. The last step of the labelling process represents the continuous monitoring and re-evaluation of the operational national facility over the lifetime of the research infrastructure.

Table 3. TNA provided by the USRL and CAO facilities via the ATMO-ACCESS project.

No.	Acronym	Institution	Facility	Applicant (PI)	Cyl contact	No. Of people	Dates	Days
1	TD-MION-MS	Karsa Oy	CAO	Jyri Mikkilä	T. Jokinen	2	07/05/22 - 13/05/22	4
2	NPF-MED	University of Groningen	CAO	Ulrike Dusek	G. Biskos	2	06/07/22 - 15/07/22	7
3	SAAA	UNIVERSITY OF TIRANA	CAO	DHURATA, PREMTI	M. Pikridas	2	26/05/23 - 05/06/23	10
4	AERO-CHEM	National Centre for Scientific Research Demokritos	CAO	Evangelia Diapouli	T. Jokinen	2	22/09/23 - 01/10/23	9
5	DAZSAL	University of Reading	USRL	Natalie Ratcliffe	F. Marenco	1	29/05/22 - 19/06/22	16
6	ASVOCUAV	Estonian University of Life Sciences	USRL	Steffen Noe	E.Bourtsoukidis	1	18/07/22 - 29/07/22	12
7	MACROSCOPIC	University of Ioannina	USRL	Nikolaos Hatzianastassiou	N. Mihalopoulos	4	09/01/22 - 01/10/23	7

8	EVIAN	Aristotle University of Thessaloniki	USRL	Dimitrios Balis	F. Marenco/ E.Bourtsoukidis	2	09/04/22 - 09/11/22	6
9	CH4LKIDIQI	LSCE	USRL	Jean-Daniel Paris	J. Sciare	1	01/11/22 - 11/11/22	12
10	UAS-GHG-T	Origins.earth	USRL	Hervé UTARD	J. Sciare	4	01/07/23 - 12/07/23	13

2.2.2 ICOS (Integrated Carbon Observation System)

ICOS (https://www.icos-cp.eu/) network consists of more than 140 measuring stations, 500 researchers, and 80 renowned universities and institutes located in 12 countries in Europe. ICOS RIs produce high-quality, standardized data on the long-lived greenhouse gas concentrations and fluxes between the atmosphere and the ecosystem. ICOS is the second most strategic Research Infrastructure for EMME-CARE (after ACTRIS). The membership in ICOS RI has very positive impacts on CARE-C's aspiration for scientific excellence. It ensures the use of the highest standards for greenhouse gas observations following stringent protocols, thus increasing the reliability of CARE- C's GHG measurements. ICOS provides an open access data portal, which would expand the visibility of the CARE-C's observations and encourage collaborative and multidisciplinary integrative analyses. The data collected within ICOS RI is a valuable source to support the decision-makers in their policy choices, which is particularly relevant for the region, already renowned for methane (CH_4) quantities generated by oil and gas production.

2.2.2.1 Building the station – start GHG measurements

CARE-C has established ICOS certified greenhouse gases measurements at CAO-Cyl since the beginning of 2020 and expanded the ICOS approved Picarro GHG measurements to a new field site located at the West coast of Cyprus in Ineia (CAO-INE). See more information in Deliverable D5.2. The new station, CAO-INE, was established during 2021 and it was identified as the optimal location for conducting long-term GHG observations in Cyprus fulfilling the ICOS criteria. The designated Picarro instrument following ICOS specifications has been operational and the sampling system is installed in CYTA's telecommunication tower with a meteorological station. Air samples are taken 35 m a.g.l. and the data automatically submitted to the ICOS database where it is openly available (https://icos-atc.lsce.ipsl.fr/panelboard/ine).

2.2.2.2 Future plans for ICOS

The process for Cyprus to integrate ICOS-ERIC will be further discussed with the Deputy Ministry of Research, Innovation, and Digital transformation (DMRID) end of 2023. The participation (and financial effort) associated with the integration of Cyprus into the ICOS network is deemed necessary considering that the EMME region is completely lacking of continuous GHG observations while being the third CO2 emitter worldwide. Hence, integration of Cyprus (and CARE-C) into ICOS will open up additional funding opportunities through the H.E. INFRA calls.

2.2.3 Long-Term Ecosystem Research Infrastructure (eLTER)

As a first step, we have made contact to the Long-Term Ecosystem Research Infrastructure (eLTER, https://elter-ri.eu) at a national level. The integration into eLTER was discussed in the WP4 meeting on September 25, 2020. An online meeting was held with Michael Mirtle from the Environment Agency in Austria (Chair of the LTER-Europe), Christoph Wohner and Jaana Bäck the national eLTER coordinator of Finland, researchers from University of Finland (EMME-CARE Advanced Partner), CARE-C and the Energy, Environment and Water Research Centre at The Cyprus Institute on 11 December 2021. In order to join the eLTER European network, we need to develop a national network and identify an

interested key contact at a stakeholder institution (Ministry, Natural Academy of Sciences, National Research Council) who needs to write a commitment letter in support of the establishment of a national LTER network. We are also enthusiastically invited to start joining eLTER meetings and activities. As an initial step after this meeting, CyI has registered the Peristerona Watershed, which covers the CAO-AMX and CAO-ORO stations (https://deims.org/6e968820-d12d-4c7b-b0e7-38d372f8c20c), and the CAO-TRO station (https://deims.org/9644c5d1-bda7-4525-baeb-f20ccc78828b) on DEIMS-SDR (Dynamic Ecological Information Management System - Site and dataset registry).

2.2.4 The Total Carbon Column Observing Network (TCCON)

The TCCON Nicosia (**Fig. 1**) in Cyprus is the first Fourier Transform Infrared Spectrometer (FTS) system, part of the international TCCON global network (http://www.tccon.caltech.edu/) to provide columnar long-term observations of the main greenhouse gases for the EMME region. TCCON Nicosia/Cyprus station's primary goals are a) to fill an observational gap in the EMME for GHGs and b) to provide a validation site for space-based instruments. The measured species are CO2, N_2O (long-lived climate forcers), CH_4, H_2O, HF (short-lived climate forcers) and CO (an indirect greenhouse gas). Cyprus, due to its limited number of cloudy/rainy days, makes it an excellent location for solar measurements.

Figure 1a. The TCCON Nicosia FTS at The Cyprus Institute.

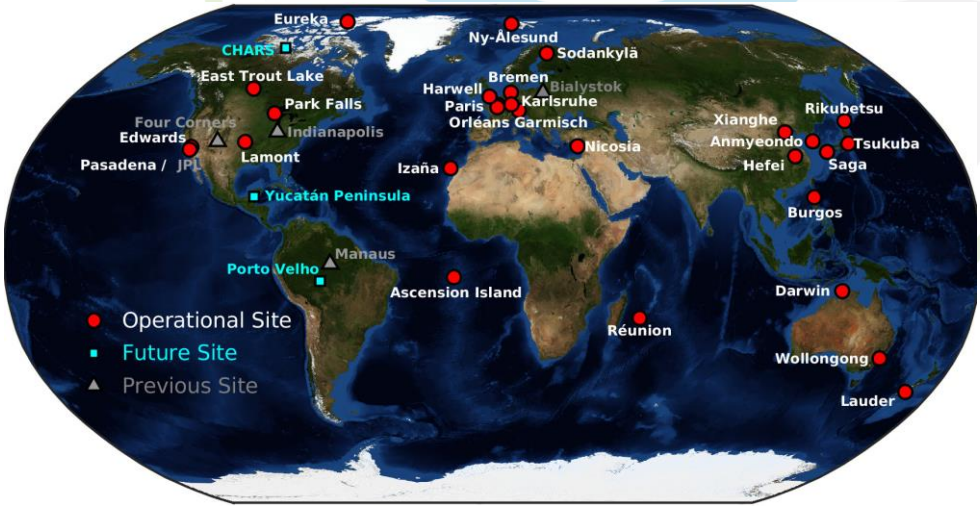


Figure 1b. The TCCON Nicosia FTS as part of the international TCCON network

2.2.4.1 TCCON Observations

Almost four years of GHG high-quality measurements have been retrieved during the beginning of the TCCON operation. **Fig. 2** depicts the temporal variability of two important GHGs in the region, CO2 and CH4. The mixing ratio of both gases denotes an increasing trend. TCCON data have been validated against AirCore balloon-based in situ observations. An example of AirCore methane profiles recorded in Cyprus is shown in Fig. 2c.

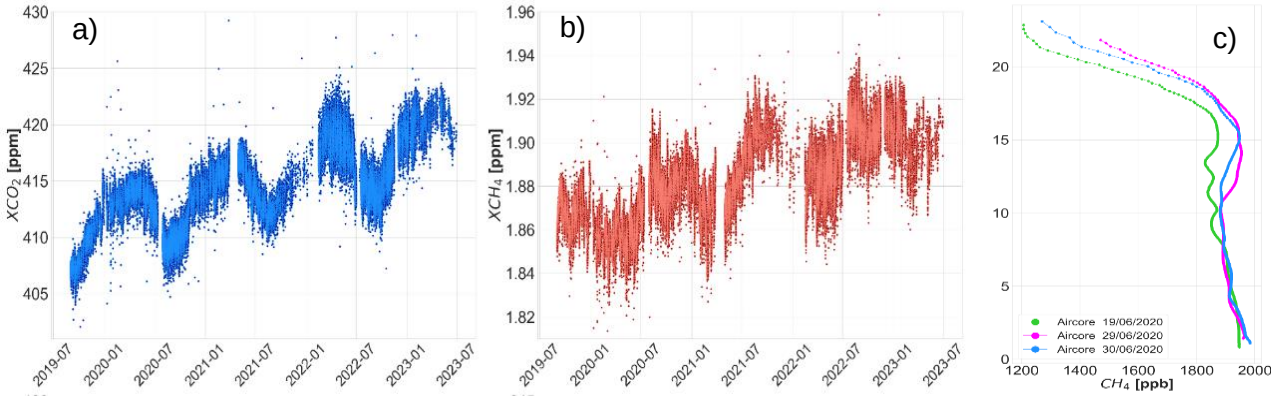


Figure 2: GHG time series of XCO2 (left) and XCH4 (middle) retrieved from TCCON Nicosia. "X" stands for total-column-average dry-air mole fractions. The right panel shows TCCON validation data obtained by AirCores in situ observations. Different colors indicate different flights (dates)

2.2.4.2 NDACC upgrade

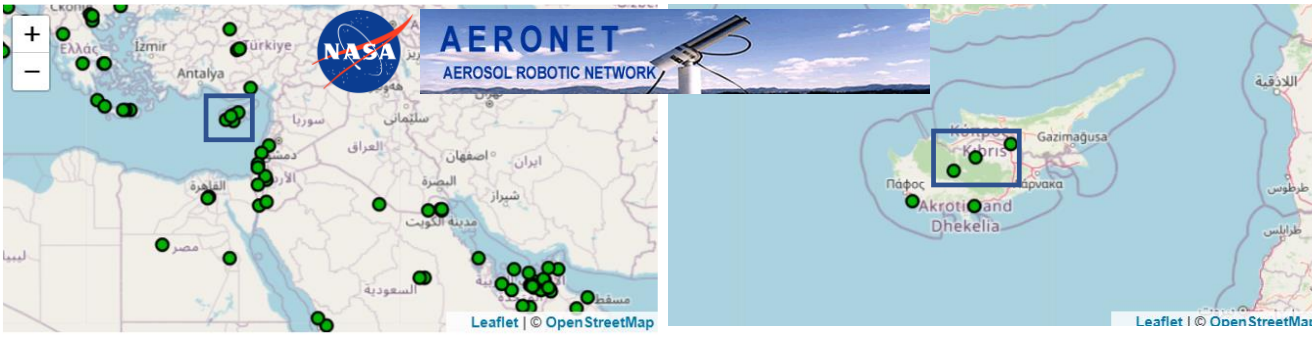
In November 2022, TCCON was upgraded to include a second (liquid-nitrogen-cooled) detector for measurements in the mid-IR. The plan is to become affiliated with the NDACC (https://ndacc.larc.nasa.gov/about) network. The new set-up allows for retrieving additional trace gas species of environmental importance including ethane (C_2H_6), ethyne (C_2H_2), formaldehyde (HCHO), hydrogen cyanide (HCN), nitrogen oxide (NO), carbonyl sulfide (COS), and ozone (O_3).

2.2.4.3 TCCON future plans

Future plans for GHG observations in the region include the employment of a light and portable EM27/SUN instrument. Measurements with this spectrometer can become affiliated to the COCCON Network (https://www.imk-asf.kit.edu/english/COCCON.php). Having a portable spectrometer provides the opportunity to deploy it in several locations, even remote with minimum maintenance, therefore offer the opportunity for satellite validations where it's needed (like deserts, e.g. Middle East and North Africa). The deployment of two of these instruments, one at a background/remote environment and one at a hot-spot (city, cattle far, power-plant) will allow capturing the enhancement in GHG amounts due to the specific emission hot-spot.

2.2.5 AERONET and other remote sensing networks

Atmospheric aerosols of a certain size can travel several hundreds or thousands of km from the source, and often the long-range transported component travels above the boundary-layer and cannot be captured by surface in-situ measurements. The Eastern Mediterranean, in particular, is affected by dust transport from the nearby deserts, pollution from Europe, Asia and the Middle East, as well as smoke from forest fires and occasional volcanic plumes. To capture these atmospheric components, a remote sensing activity has been started in the framework of EMME-CARE. All remote sensing instruments, including CIMEL CL376 lidar, radiative flux meter, two Vaisala CL51 ceilometers and three CIMEL sunphotometers are integrated in respective international networks (ICARE, E-profile and AERONET), which provide real-time, open access visualisation of the respective observations.



Location of the 3 Aeronet stations operated by the CARE-C at CAO-AMX, CAO-TRO, and CAO-Cyl

Moreover, they are expected to be integrated in the ATMO-ACCESS Pilot project implementation plan for ESA EarthCARE satellite Cal/Val support, and our scientists contribute to the PROBE and HARMONIA COST Actions. Our AERONET sites are calibrated annually by PHOTONS (LOA) and for the characterisation of our lidar we developed an own methodology which makes use of the reference system operated by ERATOSTHENES (*Papetta et al., 2023, submitted to AMT*). The lidar system will receive an upgrade from the manufacturer in early 2024.

2.2.6 European Monitoring and Evaluation Program (EMEP)

Air Quality observations at CAO-AMX are part of the EU-EMEP (www.emep.int) network since 1997. CAO-AMX participated in an intensive EMEP campaign, for VOC/O3 observations to map the role of VOCs on high ozone episodes, as the only country from Easter Europe (see other participant locations below, **Fig. 3**).

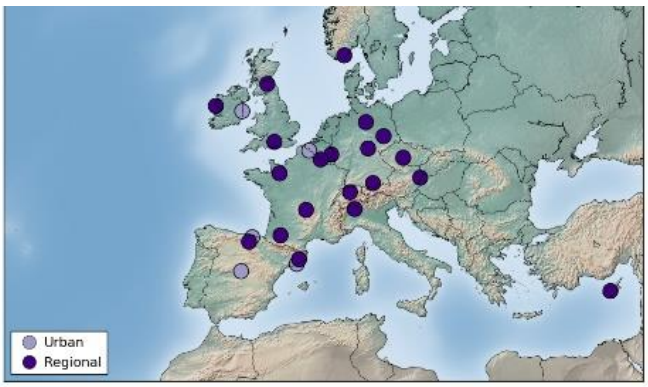
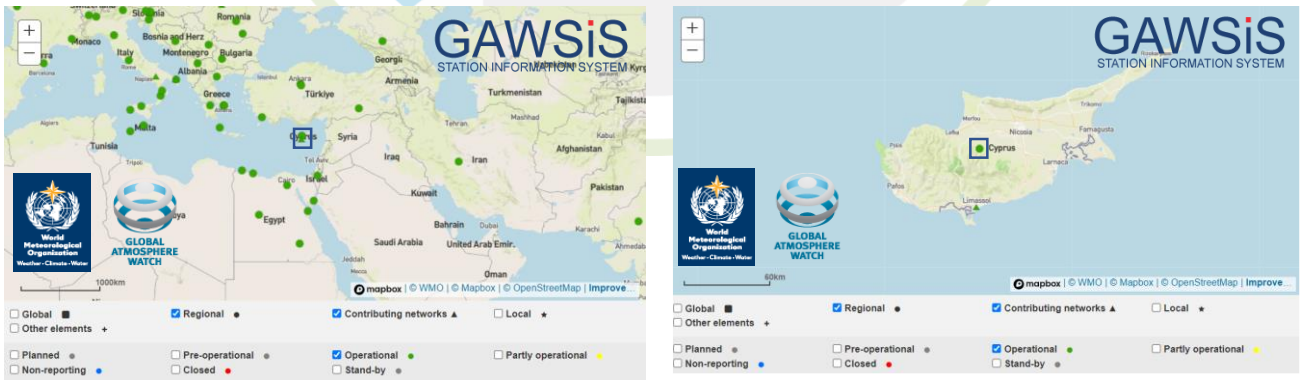


Figure 3. Participant sites for EMEP 2022 campaign.

2.2.7 WMO-GAW (Global Atmosphere Watch)

CARE-C has been contributing to the WMO-GAW (www.wmo.int; https://public.wmo.int/en/programmes/global-atmosphere-watch-programme) Regional network since Jan 2015 (https://gawsis.meteoswiss.ch/GAWSIS/#/search/station/stationReportDetails/0-20008-0-CYP). We have submitted data of aerosol scattering, absorption and submicron composition for the years 2015 and 2016 and we are in preparation to submit 4 more years of aerosol absorption data and 6 years of OC/EC data collected from the CAO-AMX station.



Contribution of CAO-AMX to WMO-GAW

3. Development in regional scientific capacities regarding the atmospheric environment (Task 5.4)

The aim of task 5.4. is to establish

a. to **develop a regional observational network connected to EU Research Infrastructure**, using the CoE as a regional node for capacity building.
b. **Actively engage its regional collaborators in high quality research**, leveraging the EMME Professorship Programme and using the same strategy developed by the Advanced Partners

This Task is expected to last 4 years. It has started in M36 (Aug. 2022) and will finish at that end of the project in M84 (Aug. 2026). Therefore, we report here only the first year of achievements. The remaining 3 years will be reported in Deliverable D5.4 (Final Report on the CoE's scientific leadership in regional Environmental observations) due in Month 84.

3.1. Development of scientific capacities with regional partners

3.1.1. EMME-CARE annual online workshop

The 1st Workshop took place over 11 - 12 October 2021, within the framework of the 2nd International Conference on Climate Change in the EMME. It gathered c. **250 participants from 36 countries**, including 12 countries of the EMME region, and featured 7 invited talks and a selection of 38 oral and 21 virtual PICO presentations on recent relevant advances in the field. Presenters came from universities, research institutions and private companies from across the EMME and beyond. More information on the CoE website (https://emme-care.cyi.ac.cy/news/news-archive/).

The 2nd Workshop took place on 1 November 2022, fully online. It gathered more than **300 participants from 41 different countries**, and featured 31 oral and 18 VPICO presentations delivered by representatives of Universities, research Institutions and private companies, actively engaged on the topics of air pollution and research innovations related on climate change. More information on the event webpage (https://emme-care.cyi.ac.cy/emme-climate-workshop/) .

The 3rd Annual Workshop is being scheduled for Autumn 2023.
More details about the workshop, including programme, book of abstracts and recordings are openly available on the EMME-CARE website.

3.1.2 EMME-CARE autumn school

With the support of its Advanced Partners, the CoE aims to become a regional node for student exchanges between EU and the EMME region, to promote international mobility and to support the organisation of intensive courses. In order to attract international students of different levels of studies (M.Sc. and Ph.D), we launched a new intensive course: the EMME-CARE autumn school.

The first EMME-CARE autumn school was organized at the CyI campus in Nicosia between 31 October – 11 November 2022. The course title was: Analysis of aerosols, air pollution and their sources in the Eastern Mediterranean. The course is organized in collaboration with lecturers from the Institute for Atmospheric and Earth System Research INAR, of the University of Helsinki, the Max Planck Institute for Chemistry (MPIC) and the French Alternative Energies and Atomic Energy Commission (CEA).

This 5 ECTS course was aimed at both M.Sc. and Ph.D. students in atmospheric and Earth system sciences. We accepted 18 students out of 36 applicants, 11 females/7 males, 6 M.Sc. students/11 Ph.D. students, who presented 11 nationalities. Two students (1 female/1male) from Middle-East, Lebanon and Jordan, were accepted to participate the course with a full stipend covering their flights and accommodation in Cyprus out of EMME-CARE. We asked the students for feedback after the course with 20-question survey and received very good grade for the course (average of 4.3/5) and 90% of the students said that they would recommend the course for their colleagues. The full course schedule, course information and lectures given during the 2-week intensive course can be found from the EMME-CARE website, under “opportunities & training”.

Figure 4. Lecturers and students of the 1st EMME-CARE autumn school.

The second Autumn school will be organized between 30 October – 3 November 2023 at the CyI campus in Nicosia. The course title will be: Atmospheric Measurements Using Miniaturised Sensors and Drones. The application portal for the course is currently open and advertised in various email lists and EMME-CARE website. This year the school will partner up with the University of Crete and Edu4Climate project to strengthen regional collaboration and student exchange.

3.1.3 Active MoUs and collaboration agreements (CA) with regional partners

The CoE has continued to strengthen and expand its regional networking and scientific collaborations, through various means. Currently, the CoE has active CA or memorandum of understanding (MoU) with 10 EMME-countries and 17 partners within (c.f. figure 5 below).

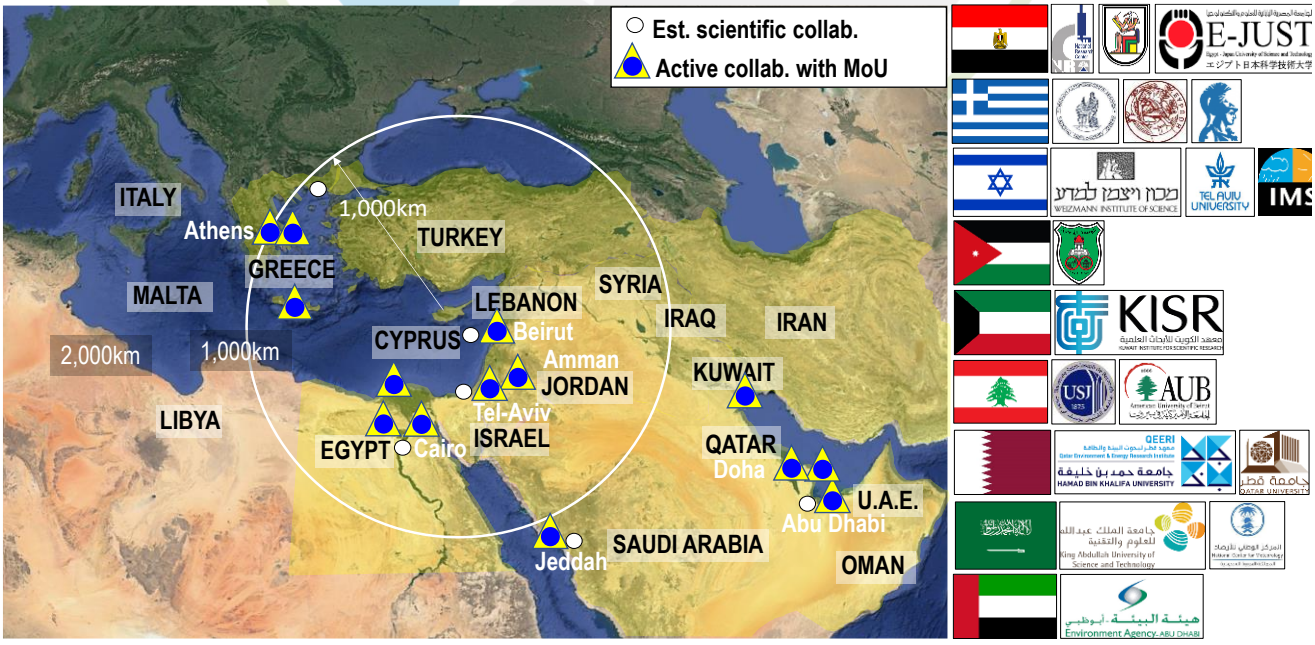


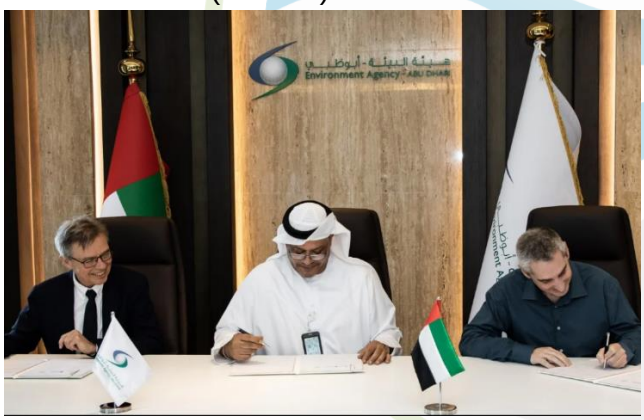
Figure 5. Established and active collaborations in the EMME area with the CoE (above) and the updated professorship program (below).

Through the EMME-CARE Professorship program the CoE has secured Faculty affiliations and scientific collaboration (via Memorandum of Understanding) with top regional institutions including:

- The National Kapodistrian University of Athens (Athens, Greece),
- The St Joseph University (Beirut, Lebanon),
- The Egyptian Japanese University of Science and Technology (Alexandria, Egypt)
- The Kuwait Institute for Scientific Research (Kuwait),
- The Qatar University (Doha, Qatar),
- The Qatar Energy & Environment Research Institute (Doha, Qatar).

In addition, the CoE has also engaged in scientific collaboration through a Memorandum of Understanding with:

- The **Israeli Meteorological Service** (IMS) for High Resolution regional climate change projections (collaboration initiated in the framework of the Climate Change Initiative).
- **Cairo University** (CU) for the establishment of educational programs (under/post-graduate curriculum on Air Pollution) in collaboration with the World Bank
- the **King Abdullah University of Science and Technology** (KAUST), contributing to the modelling component of THOFA.
- The **Environment Agency of Abu Dhabi** (EAD) for cooperation on a major atmospheric research project named Atmospheric Research Expedition to Abu Dhabi (AREAD), that took place in 2022, and marked the world first offshore atmospheric research expedition between Spain and UAE. As well as a 2023 ship campaign investigating the Transport of Hydrocarbons and Ozone Formation downwind of the Arabian Gulf (THOFA).



Signing Ceremony at the Environmental Agency of Abu Dhabi with the Cyprus Institute (CARE-C) and the Max Planck Institute (EMME-CARE Advanced Partner)

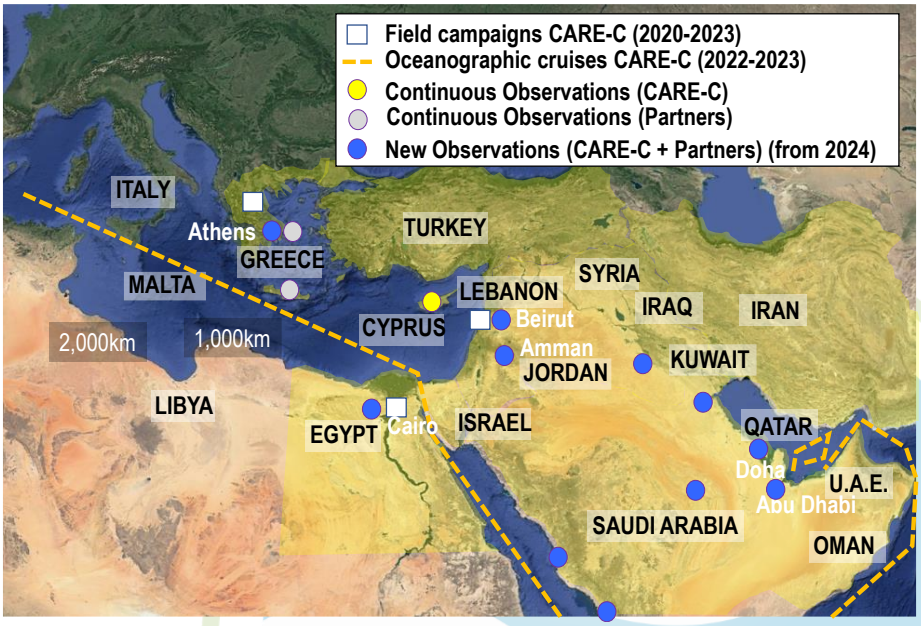
3.1.4 Publication list with regional scientific collaborators on Environmental Observations (as per WP5)

As an important KPI of the successful development of our regional scientific collaboration network, we are reporting in Annex 1, all peer-reviewed scientific publications, co-authored with colleagues from the EMME region and restricted to the Environmental Observation Department (WP5).

3.2. Establishment of regional observation networks

Regional observations (as part of Task 5.4) were expected to start from M36 (Sept. 2022). Leveraging new/existing scientific collaboration and/or funding opportunities, we have been in capacity to initiate some of these observations from the start of EMME-CARE (2020), although most of them could really start after the COVID pandemic (i.e. after mid of 2022).

We have reported in the map below all observations performed so far in EMME-CARE (2020-2023) as well as those which are planned (and financially secured) from 2024.



Regional observations performed by CARE-C:

1.
2. Field campaigns (Greece, Egypt, Lebanon)
3. Oceanographic cruises (Mediterranean, Red Sea, Gulf)
4. On-going Continuous observations (Cyprus, Greece)
5. Forthcoming observations (Lebanon, Jordan, Egypt, Saudi Arabia

A detailed description of the regional activities performed so far are presented in more details in the following.

3.2.1 Construction of Air Quality laboratory in Cairo (Egypt)

As part of the "Sustainable Development Strategy (SDS): Egypt Vision 2030," Egypt has made a commitment to reducing its fine particulate matter (PM_{10}) air pollution by 50% by 2030. Substantial progress has already been achieved, with Cairo's PM_{10} concentration having decreased by approximately 25% over the past decade. To further enhance air quality, the Government of Egypt is implementing the Greater Cairo Air Pollution Management and Climate Change Project, which is financially supported by The World Bank. This project aims to reduce air and climate emissions from critical sectors and enhance resilience to air pollution in Greater Cairo. The project is implemented by the Egyptian Ministry of Environmental (EEAA).

Through World Bank competitive tenders, **CARE-C has been engaged in 2020 to support EEAA in developing an updated source apportionment study for Greater Cairo, with a specific focus on air pollution mitigation strategies.** As a result, four (4) environmental stations have been constructed in Egypt, strategically located in Qaha (regional background), Tahrir Square (urban traffic), El Sheikh Zayed (airport), and Masr El Gedida (urban background). These stations collect PM_{10} and $PM_{2.5}$ samples once every three days, resulting in approximately 1,000 samples per year.
Additionally, an analytical laboratory has been established in Cairo, equipped with two Ion Chromatographs for determining water soluble ions, a chromatograph for analyzing sugars in ambient air samples, X-ray fluorescence analysis for trace metal and elemental detection, and OC/EC thermal-optical reflectance for quantifying the elemental carbon to organic carbon ratio. The mass of each sample is accurately determined by weighing the sample substrate before and after collection using a balance with 5-digit accuracy.

In 2021, training on source identification was provided, although it was conducted remotely due to COVID-19 restrictions.

In July 2023, CARE-C has been granted a second contract with EEAA to finalize the construction / accreditation of the Air Quality Laboratory (located at Cairo University) that is in charge of the chemical analysis of all PM samples collected within the Greater Cairo Area (GCA). This will also include a comprehensive training program that will cover aerosol sampling techniques, chemical speciation training utilizing the newly acquired analytical instruments funded by The World Bank, and data interpretation using receptor and inverse modelling techniques. The ultimate goal is to identify pollution sources in Cairo and actively work towards reducing their levels. **In July 2023, CARE-C has been awarded a second contract (through competitive tender) to support EEAA with the upgrade of the current Air Quality Monitoring network of GCA to include the monitoring of short-lived climate active species (methane, black carbon).**
These activities (supported by the Egyptian Ministry of the Environment) will contribute to better coordinate regional monitoring efforts of air pollutants and GHGs, which is among the major scientific objectives of EMME-CARE.

3.2.2 Intensive field observations in Beirut (Lebanon)

Two field campaigns were conducted in Lebanon where PM2.5 samples were collected; the first in 2014 at two sites (Urban called “Hersh” and suburban called “USJ”) in Greater Beirut and the second in 2019 at two urban-industrial sites “Zouk” and “Fiaa” (**Figure 6**). CARE-C participated in the chemical analysis of the samples along other collaborators in France, Turkey, and Lebanon. Moreover, sources samples were collected in order to establish proper chemical profiles of some important sources in the region.

The organic fraction of PM2.5 was comprehensively characterized with around 60 compounds identified and quantified. A characteristic ratio of PAHs was determined for heavy fuel oil combustion from the power plant. Moreover, specific V/Ni ratios were determined based on the air mass origin. Source apportionment using PMF was conducted along with air mass back trajectories showing that Crustal Dust has generally the highest contribution even though Lebanon does not have any deserts, followed by Secondary Inorganic aerosols mainly from long range sources (mainly Turkey and Eastern Europe), then on-road traffic. The health risk assessment showed that the PM2.5 compositions at the 4 sites exhibit high values for cancer risk, exhibiting importantly the acceptable value of the USEPA. Data treatment and analysis is still ongoing.

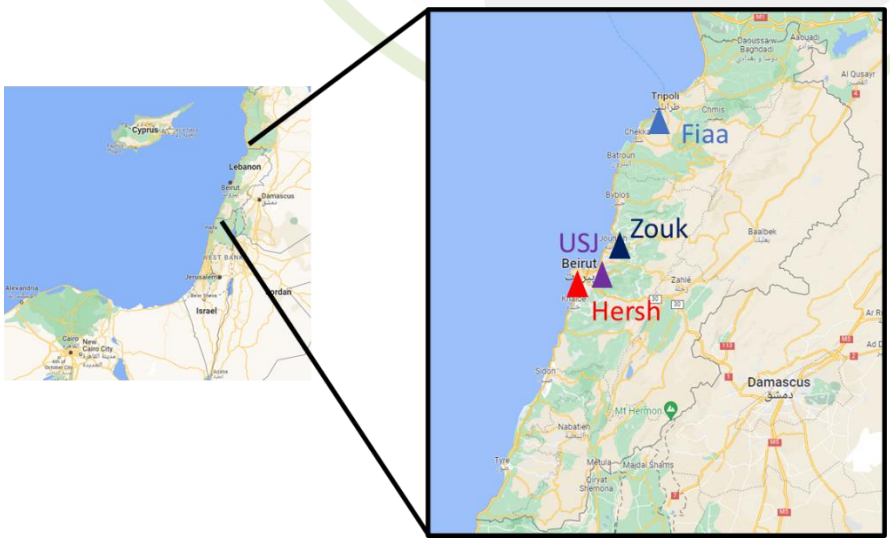


Figure 6. The map of sampling sites in Lebanon.

3.2.3. Intensive field observations in Cairo (Egypt)

A field campaign was conducted in December 2019 and January 2020 in Greater Cairo Area at the National Research Center (**Figure 7**). PM2.5 filters were collected daily over 24 hours while PM1 filters were sampled every 6 hours from 23:00 to 11:00 during the first month and 11:00 to 23:00 during the second month of sampling. Chemical analysis of the filters has been conducted at the CyI and Saint Joseph University of Beirut.

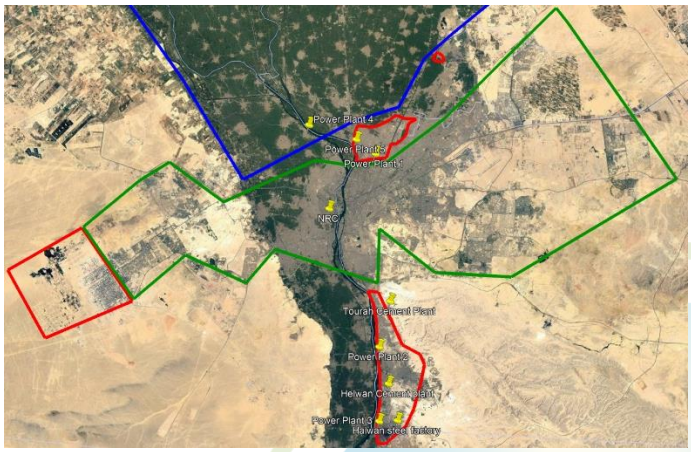


Figure 7. Land use of Greater Cairo Area along with the main energy and chemical industries along the NRC sampling site. Red polygons are industrial areas, green polygons are residential areas, while the blue polygon is agricultural and residential area

The average concentrations for 6-hour sampling and standard deviations of reconstructed PM1 at the sampling time during the entire study period were 59.58 ± 33.80 μg m^{-3}. On average the fractions of major chemical compositions followed the order Ions, Organic Matter, Crustal Matter, Elemental Carbon, and Trace Elements accounting for 38 %, 29.8%, 23.9%, 6.5 %, 1.6% respectively. The percentage of SNA + Cl (38 %) was much higher than all the other species and even higher than that of OM. PM2.5 concentrations had an average of 147 ± 78 μg m^{-3}. **Figure 8** shows the temporal variation of the concentrations of POC and SOC during the field campaign with SOC concentrations reaching 25.5 μg/m^3, while POC concentrations reach 19.45 μg/m^3. It is interesting to note the important co-variation of the OC/EC with the SOC. The OC/EC ratio over the field campaign showed a dominance of the traffic source. The contribution of SOC to the total OC was 45%, while POC contributes to 55%, indicating that the high temperature and the intense solar radiation do provide favourable conditions for the high OC concentrations at the site.

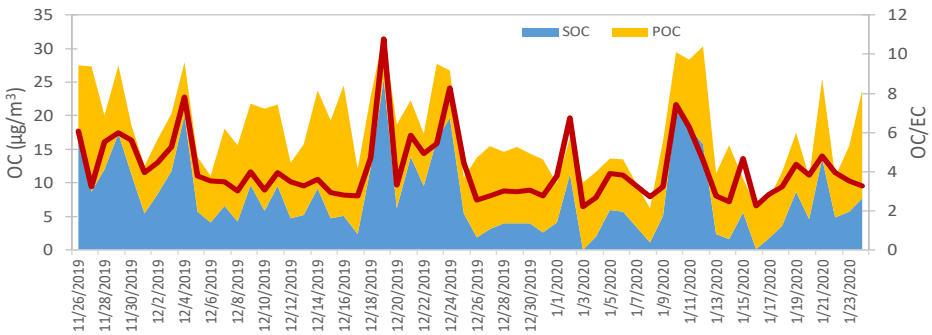


Figure 8. Primary Organic Carbon (POC), Secondary Organic Carbon (SOC), and OC/EC ratio during the intensive field campaign of PLOCAIR

The further scientific exploitation of these observations is currently ongoing (PhD student) with the first peer-review publication to be submitted in August 2023.

3.2.4. Intensive field observations in Saudi Arabia

In Saudi Arabia sampling and analysis of filters will be done to support the regional center of WMO Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS, https://community.wmo.int/en/activity-areas/gaw-sand-and-dust-storm-warning-advisory-and-assessment-system-sds-was). The mission of the SDS-WAS is to enhance the ability to deliver timely quality sand and dust storm forecasts, observations, information and knowledge to users through a regional center and an international partnership.

Samples will be collected at 8 stations in Saudi Arabia covering different sites regional, rural, traffic and industrial. Daily samples will be collected for a yearlong period at both PM10 and PM2.5 fractions for chemical composition determination (ions, carbonaceous components and metals) and source apportionment characterization using statistical tools (e.g PMF). **CARE-C will be responsible for the entire PM chemical analyses and PM source apportionment. Filter sampling is expected to start in September or October 2023**

3.2.5. Fine aerosols sources and their gas precursors in Cairo, Egypt (POLCAIR)

Two field campaigns have been conducted in the greater Cairo Area, the first over two months December 2019 and January 2020 designated as Intensive Observation Period, while the second from August 2020 to August 2021 designated as Extended Observation Period. The field campaigns are part of the POLlution in CAIRo (POLCAIR) project in collaboration with Saint Joseph University of Beirut – Lebanon, Université Clermont Auvergne – France, IMT Lille Douai – France, Université du Littoral Côte d'Opale – France, Cairo University – Egypt, the National Research Center – Egypt, and The Cyprus Institute.

The POLCAIR project has the specific goal of evaluating the sources of anthropogenic pollution in the atmosphere and its effects on public health within Greater Cairo.

During the first field campaign, an unprecedented number of gaseous and particulate pollutants were measured. The monitoring activities were conducted on the rooftop of the National Research Center's Physics Department, situated in the heart of Cairo. The main focus was to continuously monitor the detailed physico-chemical composition of fine particles and gaseous compounds in the atmosphere, while also assessing real-time tracers to determine the origin of pollution. This was made possible through the utilization of state-of-the-art instruments such as Q-ACSM, SMPS, Aethalometer, OPC, HTDMA, PTRMS, and GC-FID. Additionally, offline measurements were taken for particulate and gaseous compounds, involving PM1, PM2.5, PM10 filter sampling, and VOC sampling.

The Extended Observation Period focused on PM2.5 filter sampling and VOC active sorbent tube sampling to monitor in both phases, i.e. gaseous and particulate, some selected chemical compounds tracers of pollution sources and also with high impact on health.

Figure 9. Location of the POLCAIR site in Greater Cairo Area.

The valuable data collected through these campaigns will contribute to a more precise understanding of pollution sources and their impact on public health especially in Egypt. Furthermore, it will aid in the accurate assessment of emissions in this climate-sensitive region of the world.

3.2.6. The Atmospheric Research Expedition to Abu Dhabi (AREAD)

The Atmospheric Research Expedition to Abu Dhabi (AREAD) started on 25th November 2022 from Vigo, Spain in the North Atlantic and traversed the Mediterranean Sea, Gulf of Suez, Red Sea, Gulf of Aden, Arabian Sea, Gulf of Oman, ending in the Abu Dhabi, UAE water in 20th December, covering a distance of more than 10,000 km (**Figure 10**).

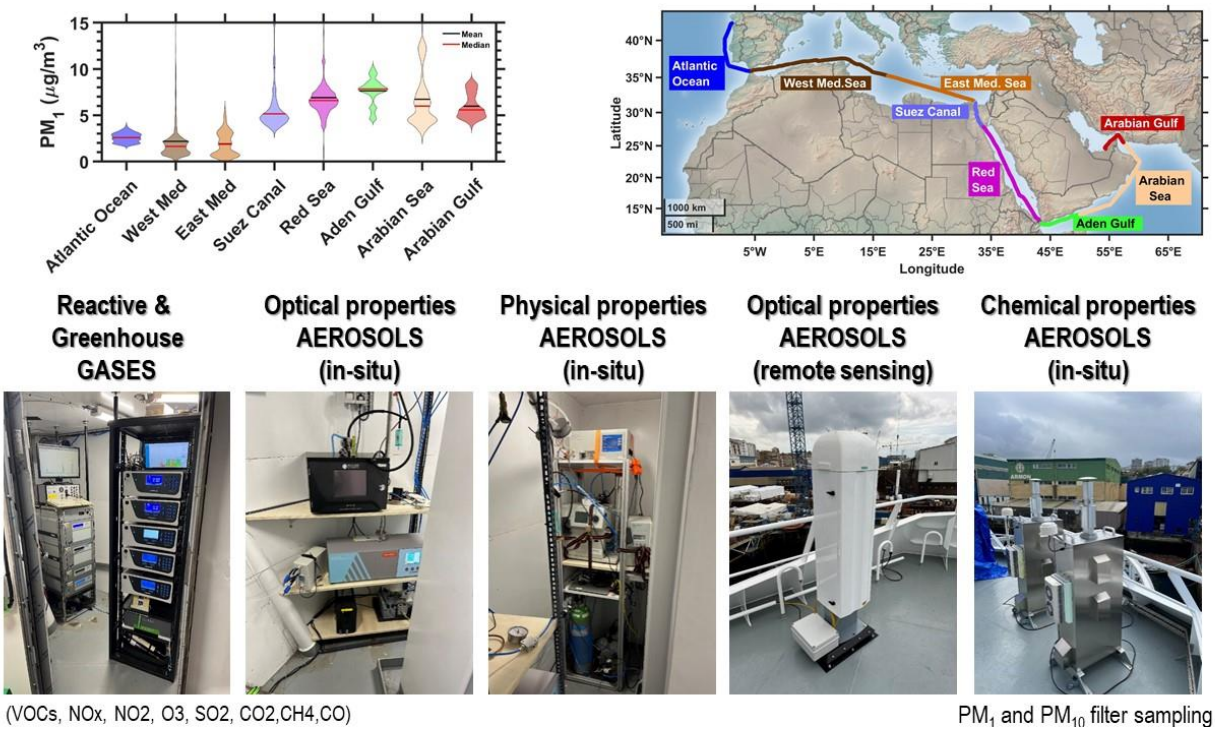


Figure 10. Ship route of AREAD campaign with pictures of the instrumentation used. First results regarding PM_1 mass are also shown.

It shows the EAD research vessel, named JAYWUN, fitted with advanced monitoring equipment supplied and operated by researchers of CARE-C, in collaboration with LSCE and MPIC, both EMME-CARE advanced partners. It was designed to complement the AQABA (Air Quality and Climate Change in the Arabian Basin) campaign that took place in 2017. While AQABA focused on monitoring pollution during the summer months of July and August, AREAD aimed to observe pollution during the winter month of December. Throughout the campaign, key aerosol and gas parameters were monitored, all of which were also included during AQABA, but using one tenth of the space that was available (17.4 m^2) then. These include measurements on NMHCs, ozone (O_3), nitric oxide (NO), nitrogen dioxide (NO_2),

sulfur dioxide (SO_2), greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), and carbon monoxide (CO) as well as particulate mass concentration (PM1, PM2.5, PM10), aerosol absorption and scattering in the PM10 range. During this campaign, a unique spectrum of environmental conditions was encountered. In the Atlantic Ocean we encountered clean, pristine air, whereas in the Red Sea we met polluted, dusty air from Africa. In the Middle East, the air was polluted by urban outflow and exhausts from ships. In the Persian Gulf, by contrast, the main pollutants were from petrochemical emissions. The measurements obtained during the AREAD campaign are expected to play a crucial role in validating and improving computer models that simulate atmospheric processes. Furthermore, the data collected will contribute to understanding the impact of these processes on public health and climate change, particularly in the Middle East region. The campaign aimed to provide critical information that can aid in decision-making and developing strategies to mitigate the effects of pollution and climate change.

3.2.7. Transport of Hydrocarbons & Ozone Formation downwind of the Arabian Gulf (THOFA)

Following the AREAD ship campaign, the collaboration with the EAD was further strengthened through focused environmental observations in the Arabian Gulf. Atmospheric observations over the Arabian Gulf region are extremely sparse, despite their global significance due to gaseous emissions from the extensive Oil and Gas (O&G) operations and rapid urbanization. In June 2023, the second shipborne campaign showcased the scientific capacity of the newly established CoE to lead critical environmental observations in the EMME region. The investigation on the formation of tropospheric ozone, one of the most intricate atmospheric pollutants, in the world's most understudied hotspot, was led by CARE-C. This effort involved coordinating a team consisting of six institutes (CyI, EAD, MPIC, LSCE, University of Bremen, KAUST) with team members from 12 different nationalities.

A significant air quality challenge in the Middle East is the elevated levels of tropospheric ozone, a potent greenhouse gas that has harmful effects on human health and the environment. Unlike primary pollutants that are directly emitted, ozone is a secondary air pollutant formed through chemical reactions between nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight. The production of ozone is particularly efficient in the Middle East, which experiences the highest concentrations globally. Understanding the non-linear and highly complex process of ozone formation, where even minor changes in VOCs or NO_x can significantly impact the dynamics of ozone production, is crucial for developing effective air quality management strategies.

To address this environmental challenge, **CARE-C proposed the use of EAD's ship vessel to investigate the Transport of Hydrocarbons and Ozone Formation downwind of the Arabian Gulf** (THOFA, **Figure 11**). This pioneering initiative aimed towards a comprehensive examination of both the transportation and the subsequent transformation of hydrocarbons (i.e. VOCs) discharged from Oil and Gas (O&G) operations, alongside nitrogen oxides emitted from ships and urban centers. Recognizing the scientific significance and mitigation strategy development potential, EAD has granted the proposal by offering the ship vessel, alongside their scientific team.

Figure 11. a. The shipborne mobile platform from the partner institution (Environment Agency Abu Dhabi, UAE), **b**. Planning of routes before the start of the campaign, and **c**. The inlets of the equipment installed inside the ship.

Leveraging the expertise of CoE's advanced partners, the campaign received support from scientific equipment provided by EMME-CARE Advanced Partners (MPIC and LSCE). Moreover, through the CoE's affiliate professorship program, we established scientific connections with the University of Bremen, which offered valuable assistance in the form of tailored air mass trajectory forecasts that guided the development of our sailing plans. Furthermore, our project's modelling team is affiliated with regional partners, including KAUST from Saudi Arabia.
The campaign has successfully concluded at the end of June 2023, having collected a unique dataset that will help the team understand the ozone formation processes in Middle East. THOFA has also collected invaluable data for greenhouse gases that will help better assessing the carbon footprint of the entire Arabian Basin. Notably, the CoE has demonstrated the ability to set up a mobile laboratory inside a ship vessel and collect invaluable air quality data that aim to address the extreme ozone pollution hotspot.

3.2.8. Residential biomass burning in Ioannina (Greece)

Urban pollution during the winter season attracts air quality research in numerous urban centres around the world. Biomass combustion releases a complex array of reactive trace gases, specifically VOCs that pose significant challenges to air quality and human health. Although biomass burning has been extensively studied in forest ecosystems, understanding the atmospheric chemistry and impact of emissions on air quality in urban environments remains challenging due to complex sources and burning materials. To address this challenge, the CoE utilized an established mobile laboratory from a partner institution (National Observatory of Athens; NOA) to investigate the VOC emission rates and atmospheric chemical processing of predominantly wood burning emissions in a carefully selected urban centre in Greece.
Funded by EMME-CARE, the CoE possesses an advanced Proton Transfer Reaction – Time of Flight – Mass Spectrometer, enabling real-time and highly accurate monitoring of volatile organic compounds (VOCs). To leverage this capability for regional environmental observations, CARE-C took the lead in investigating atmospheric gases emitted from residential biomass burning. The campaign focused on Ioannina, Greece, a city situated in a valley surrounded by mountains, known for its low temperatures and wind speeds, which contribute to pronounced pollution events during the winter season. Collaborating with NOA, the local University of Ioannina, and the University of Crete, the CoE aimed to gather comprehensive data on emission rates and the air quality implications of residential biomass burning.
The study has resulted in the submission of the first scientific article from the Ioannina winter 2021/22 campaign. This article, led by CARE-C and titled "*Emission of volatile organic compounds from residential biomass burning and their rapid chemical transformations*," is currently under review for publication in the high-impact journal Science of the Total Environment. It emphasizes the need for

increased regulation and mitigation measures to address the significant impact of residential wood burning on urban air quality.

Figure 12. a. The mobile laboratory used in the campaign, **b.** photo during the campaign, visualizing the atmospheric pollution from intense wood burning, and **c.** exceptionally high hourly values of OH reactivity (atmospheric reactivity indicator), as they were derived from the continuous VOC observations.

3.2.9. Construction of a regional Pollen monitoring network

Bioaerosols and in particular pollen are known to impact human health. Moreover, it is suspected that their allergenicity can be enhanced in dusty environments. In this context we have studied the variability and the seasonality airborne pollen grains impacting the capital city of Nicosia. The main objectives of these observations are (i) to understand the temporal variability of pollen grains and (ii) to investigate the potential source points of aeroallergens using a source-receptor model. To achieve these objectives, a spore trap (VPPS 2000) has been deployed at the Cyprus Atmospheric Observatory of Nicosia (35.14°N, 33.38°S) from 2018 to 2023. The instrument has been installed on the roof of the building, at 15 meters above the ground to obtain representative measurements of the regional signal as illustrated by **figure 13**.

Figure 13. Spore trap VPPS 2000 on the roof of the Cyprus Institute of Nicosia (Athalassa campus).

Pollen concentrations can be extremely variable from a year to year and the impact of precipitation and heating waves can affect the atmospheric concentrations (**Figure 14**).

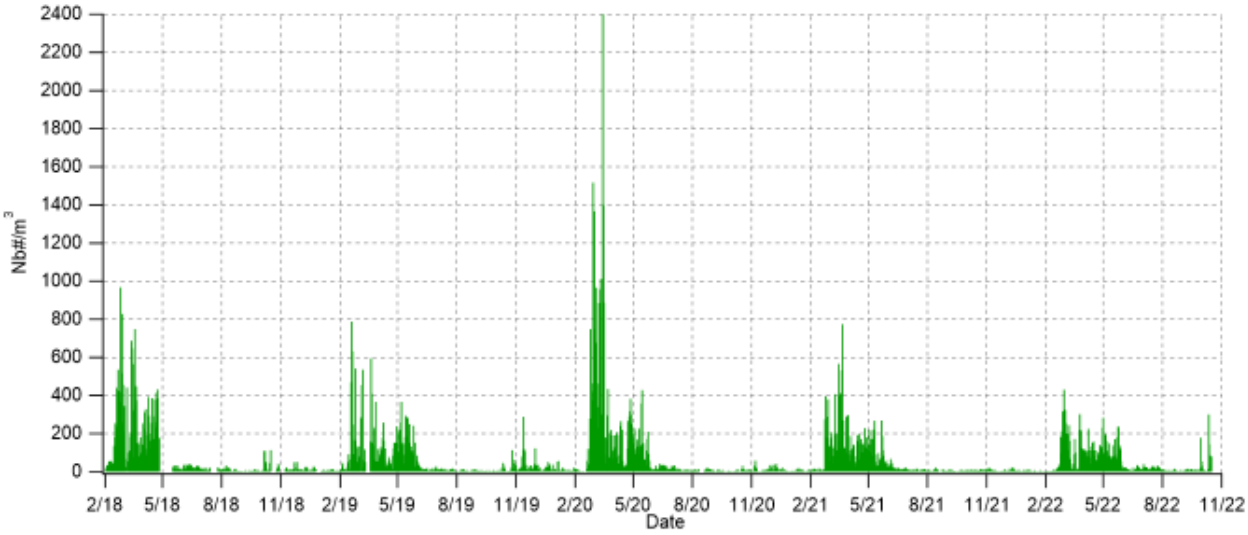


Figure 14. Daily variability of Pollen from Feb 2018 to Nov 2022.

The main pollen season starts mid-February with elevated concentrations of Cupressaceae-Taxaceae and ends in early June with Poaceae. Interestingly, pollen grains were also detected over the autumn and winter periods (Figure 15). To date, the results obtained showed that 73% of the total pollen grains sampled at the Nicosia site were allergenic species.

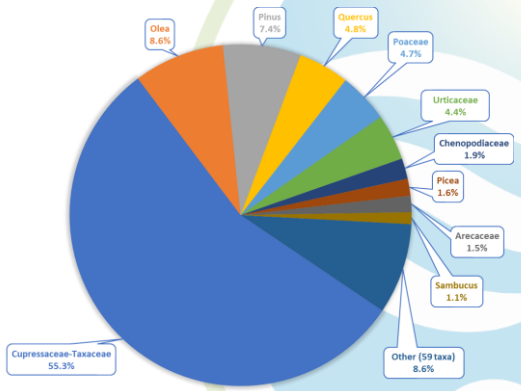


Figure 15. Relative abundance of the major pollen Feb. 2018 to Nov. 2022

We know now that Cyprus island is influenced both by local and long-range sources from continental Europe, the African continent or the Middle East. We observed that the main source of pollen originates from North West to South West but secondary pollen source was associated to North East to South East with moderate winds. This last point remains to be investigated in the future.

Another spore trap was moved from Athens to Heraklion (Crete) in 2022 and has been operational since. The data analysis is ongoing. **One more spore trap will be installed in Beirut, Lebanon** around the beginning of 2024 in order to improve regional coverage of pollen observations in the EMME.

4. Future plans to expand regional coverage of observations

4.1. Beirut (Lebanon) Atmospheric Observations Supersite

New field campaigns are being prepared to begin in Beirut in Jan 2024. The site will be located at the Saint Joseph University in Mansourieh – Greater Beirut Area (figure 16). Two field campaigns will be considered: one of shorter period (aiming at 1 year) designated as Intensive Observation Period with a full extensive set of measurements, while the second campaign would be of longer period but with fewer parameters to monitor and a lighter setup designated as Extended Observation Period. The field campaigns will be in collaboration with Paul Sherrer Institute – Switzerland and Saint Joseph University of Beirut, our Regional partner. The measurements will encompass continuously monitoring the detailed physico-chemical composition of fine particles and gaseous compounds in the atmosphere and quantifying in real time different tracers of the origin of this pollution. Online state of the art instruments will be used including Q-ACSM, SMPS, Aethalometer, OPC, HTDMA, PTRMS, etc. as well as offline measurements of particulate and gaseous compounds (PM1, PM2.5, PM10 filter sampling, VOC sampling, etc.).

Figure 16. The new Beirut supersite location.

4.2 Amman (SMEAR-Jordan) Atmospheric Observations Supersite

We are seeking for close collaboration between the Coe and and University of Jordan (namely our Environmental and Atmospheric Research Laboratory (EARL) and University of Helsinki in order to establish a new SMEAR station in Amman, Jordan. In the beginning, the station will be equipped with instrumentation to measure:

- Ultrafine particle number concentrations down to 2.5 nm
- Fine particle size distributions (SMPS 10 – 650 nm)
- Particle size distributions (OPS 0.3 – 10 μm)
- High volume sampling of PM2.5 or PM10 aiming at gravimetric, OC/EC, ions, and elemental.
- Local weather conditions on site

Additional, portable instruments for measurement campaigns are available such as :

NanoScan SMPS (10 – 450 nm), OPS (0.3 – 10 µm), CPC, P-Trak, AeroTrak, DustTraks and Low-Cost Sensors

Collaboration with the Ministry of Environment was approved to make use of their monitoring data measured by the National Air Quality Monitoring Stations (about 8 background stations with PM and gases) – this is through our new Ph.D. student to be admitted to the graduate program at INAR and in the graduate program at CyI. The CoE is looking into signing an MoU with the University of Jordan by the end of the year 2023.

4.3 Cairo (Egypt) Atmospheric Observations Supersite

Leveraging the ongoing collaborations with several major research organizations in Cairo (Cairo University, NRC) and the Egyptian Ministry of the Environment (EEAA), CARE-C will explore the possibility to establish an atmospheric supersite in the city center of Cairo in order to better capture long-term trends of air pollutants and GHG in this megacity. This activity will be initiated once the supersites of Beirut and Amman will be fully operational (i.e. years 2025-2026).

ANNEX 1 – Publication List with Regional (EMME) Partners

YEAR 2019 (start of EMME-CARE)

Composition and variability of gaseous organic pollution in the port megacity of Istanbul: source attribution, emission ratios and inventory evaluation by Thera, B. T. P., Dominutti, P., Öztürk, F., Salameh, T., Sauvage, S., Afif, C., Çetin, B., Gaimoz, C., Keleş, M., Evan, S., and Borbon, A. (2019). **Atmos. Chem. Phys., 19, 15131–15156**; This study focuses on VOC measurements in Istanbul – Turkey and identifies for the first time the sources of VOCs using PF source apportionment model and estimates their contributions to VOC ambient concentrations. It also established emission ratios relative to CO and assesses three downscaled global emissions inventories (EDGAR, ACCMIP, and MACCity).

YEAR 2020

Determination of Gaseous and Particulate Emission Factors from Road Transport in a Middle Eastern capital by Abdallah, C., Afif, C., Sauvage, S., Borbon, A., Salameh, T., Kfoury, A., Leonardis, T., Karam, C., Formenti, P., Doussin, J.F., Locoge, N., Sartelet K. (2020). Transportation Research Part D: Transport and Environment, 83, 102361; This study quantifies the Emission Factors (EF) of traffic-related gaseous (CO, NOx, speciated VOC and IVOC) and particulate (PM2.5) pollutants inside the Salim Slam urban tunnel in Beirut, Lebanon. The EF determined showed general higher values than those reported in recent studies, even for speciated NMVOC. Moreover, IVOC species from gaseous phase were reported for the first time in the region. The comparison of the EF to those calculated through EMEP or IPCC methodologies shows the need to take local practices while establishing national emission inventories.

Long-term variability, source apportionment and spectral properties of black carbon at an urban background site in Athens, Greece by Liakakou, E., Stavroulas, I., Kaskaoutis, D.G., ... K Oikonomou, J Sciare, Gerasopoulos, E., Mihalopoulos, N. Atmospheric Environment, 2020, 222, 117137. This study aims to delineate the characteristics of Black Carbon (BC) in the atmosphere over Athens, Greece, using 4-year (May 2015–April 2019) Aethalometer (AE-33) measurements.

YEAR 2021

PM2.5 characterization of primary and secondary organic aerosols in two urban-industrial areas in the East Mediterranean by Fadel, M., Ledoux, F., Farhat, M., Kfoury, A., Courcot, D., Afif, C. (2021). Journal of Environmental Sciences, 101, 98-116; This study aims to comprehensively analyze the organic fraction of PM2.5 samples collected for a year in two urban sites under industrial influence in Lebanon. Around 60 organic compounds have been analyzed and reported, some for the first time in the region. A characteristic ratio of PAHs was determined for heavy fuel oil combustion from the power plant

Prenatal exposure to criteria air pollutants and associations with congenital anomalies: A Lebanese national study by Al Noaimi G., Yunis K., El Asmar K., Abu Salem F., Afif C., Ghandour L.A., Hamandi A., Dhaini H.R. (2021). Environmental Pollution, 28115, 117022; This study examines the association between maternal exposure to criteria air pollutants and birth defect risk in Lebanon. Results show that maternal exposure to PM2.5 during the first trimester is significantly associated with a higher overall birth risk and neural tube defects. NO2 and SO2 showed also impact on birth defect on selected features. The findings set the basis for building a novel birth defect risk prediction model.

Annual exposure to polycyclic aromatic hydrocarbons in urban environments linked to wintertime wood-burning episodes by Tsiodra, I., Grivas, G., Tavernaraki, K., ...Oikonomou K.,

Tsagkaraki M., Nenes, A., Mihalopoulos, N., Atmospheric Chemistry and Physics, 2021, 21(23), pp. 17865–17883. A year-long sampling campaign in Athens, Greece, where more than 150 samples were analysed for 31 PAHs and a wide range of chemical markers were used in combination with Positive Matrix Factorization (PMF) to constrain the temporal variability, sources and carcinogenic risk associated with PAHs

YEAR 2022

- ***Human health risk assessment for PAHs, phthalates, elements, PCDD/Fs, and DL-PCBs in PM2.5 and for NMVOCs in two East-Mediterranean urban sites under industrial influence by Fadel, M., Ledoux, A., Afif, C., Courcot, D. (2022). Atmospheric Pollution Research, 13, 101261****;* This paper presents, for the first time in the literature, the cancer and the non-cancer risks associated with more than 70 species including PAHs, phthalates, elements, dioxins, furans, and dioxin-like PCBs in the particulate phase and also NMVOCs. The study targeted two urban sites under industrial influence in Lebanon. The health risks were evaluated for the three exposure pathways and for different age categories. Several species presented cancer risk values higher than the threshold limit, emphasizing on their major impact on human health.
- ***Chemical profiles of PM2.5 emitted from various anthropogenic sources of the Eastern Mediterranean: Cooking, wood burning, and diesel generators by Fadel, M., Ledoux, F., Seigneur, M., Oikonomou, K., Sciare, J., Courcot, D., Afif, C. (2022). Environmental Research, 211, 113032;*** This study aims at establishing chemical profiles for various anthropogenic sources commonly observed in the East Mediterranean region due to the lack of chemical profiles available for the region. These sources include charcoal grilling of beef and chicken, general cooking activities, wood burning, and emissions from non-road diesel generators. The study includes a full chemical characterization of PM2.5 emitted from these sources including dioxins and furans, accompanied by the evaluation of several diagnostic ratios.
- ***Methods for the assessment of health risk induced by contaminants in atmospheric particulate matter: a review by Fadel, M., Courcot, D., Afif, C., Ledoux, F. (2022). Environ Chem Lett 20, 3289–3311***; In this review, a compilation of the different methods used to assess the health risk related to airborne particulate matter exposure is presented. The originality of this paper is its unique consideration of multiple routes of exposure as well as various classes of compounds. A critical analysis and the limitations of the health risk assessment methodologies were also included in this review.
- ***Evidence of stockpile contamination for legacy polychlorinated biphenyls and organochlorine pesticides in the urban environment of Cyprus (Eastern Mediterranean): Influence of meteorology on air level variability and gas/particle partitioning based on equilibrium and steady-state models by Iakovides, M., Oikonomou, K., Sciare, J., Mihalopoulos, N., Journal of Hazardous Materials, 2022, 439, 129544.*** The present study investigated comprehensively the atmospheric occurrence and fate of an extensive range of polychlorinated biphenyls (PCBs; forty-two congeners), organochlorine pesticides (OCPs; twenty-seven emerging and legacy agrochemicals) and polycyclic aromatic hydrocarbons (PAHs; fifty parent and alkylated members, including the non-USEPA-16 listed toxic ones), in both gas and particulate phase of the scarcely monitored atmosphere over Cyprus for the first time.
- ***3-Dimensional analysis of long-range transported particulate matter to the Eastern Mediterranean: Implication for the chemical components of PM1 and PM10 by Dimitriou, K., Pikridas, M., Oikonomou, K., ...Vassiliadou, E., Mihalopoulos, N. A. Atmospheric Pollution Research, 2022, 13(7), 101485***. This study aims to better characterize the location of the strong regional emitters of aerosols affecting the Eastern Mediterranean basin, through the use of a recently developed three-dimensional (3D) version of a Concentration Weighted Trajectory (CWT) model which can identify the prevalent transport pattern of polluted air masses as a function of their altitude (0 m≤ Layer 1< 1000 m (near ground layer), 1000 m≤ Layer 2< 2000m (intermediate layer), 2000m≤ Layer 3 (upper layer).
- ***Impacts of severe residential wood burning on atmospheric processing, water-soluble organic aerosol and light absorption, in an inland city of Southeastern Europe by Kaskaoutis, D.G., Grivas, G., Oikonomou, K., ...Gerasopoulos, E., Mihalopoulos, N. Atmospheric Environment, 2022, 280, 119139.*** This study examines the concentrations and characteristics of carbonaceous aerosols (including saccharides) and inorganic species measured by PM2.5 filter

sampling and a multi-wavelength Aethalometer during two campaigns in a mountainous, medium-sized, Greek city (Ioannina).

- ***Severe atmospheric pollution in the Middle East is attributable to anthropogenic sources by Osipov, S., Chowdhury, S., Crowley, J. N., Tadic, I., Drewnick, F., Borrmann, S., Eger, P., Fachinger, F., Fischer, H., Predybaylo, E., Fnais, M., Harder, H., Pikridas, M., Vouterakos, P., Pozzer, A., Sciare, J., Ukhov, A., Stenchikov, G. L., Williams, J., & Lelieveld, J. (2022). Communications Earth & Environment, 3(1), Article 1***. https://doi.org/10.1038/s43247-022-00514-6; Collaboration with MPIC. Summary of optical aerosol characteristics in the M. East and Mediterranean Sea. The study has climatic relevance.
- ***European aerosol phenomenology − 8: Harmonised source apportionment of organic aerosol using 22 Year-long ACSM/AMS datasets by Chen, G., Canonaco, F., Tobler, A., Aas, W., Alastuey, A., Allan, J., Atabakhsh, S., Aurela, M., Baltensperger, U., Bougiatioti, A., De Brito, J. F., Ceburnis, D., Chazeau, B., Chebaicheb, H., Daellenbach, K. R., Ehn, M., El Haddad, I., Eleftheriadis, K., Favez, O., … Prévôt, A. S. H. (2022).*** Environment International, 166, 107325. https://doi.org/10.1016/j.envint.2022.107325; European wide study on source apportionment that includes the Cyprus Atmospheric Observatory results. Review of submicron aerosol sources across Europe.

YEAR 2023

- ***Comprehensive chemical characterization of PM2.5 in the large East Mediterranean-Middle East city of Beirut, Lebanon by Fakhri, N., Fadel, M., Öztürk, F., Keleş, M., Iakovides, M., Pikridas, M., Abdallah, C., Karam, C., Sciare, J., Hayes, P., Afif, C. (2023). Journal of Environmental Sciences, 133, 118-137***; This study aims to investigate the chemical composition of PM2.5 including primary and secondary organics in the Greater Beirut Area of Lebanon during the hot season. The main objective is to highlight the potential sources of PM2.5, whether natural or anthropogenic, local or transported by air masses over long distance, that contribute to the air quality of the capital city. A cancer risk assessment for elements bound to PM2.5 showed exceedances compared to the threshold limit.
- ***Identification and apportionment of local and long-range sources of PM2.5 in two East-Mediterranean sites by Fadel M., Courcot D., Seigneur M., Kfoury A., Oikonomou K., Sciare J., Ledoux F., Afif C. (2023). Identification and apportionment of local and long-range sources of PM2.5 in two East-Mediterranean sites. Atmospheric Pollution Research, 14, 101622***; This paper focuses at first on the comprehensive chemical characterization of PM2.5 samples in two sites in Lebanon, for a one-year campaign at each site. It also identifies the sources of PM2.5 using PMF source apportionment model and estimates their contribution while including organic tracers for the first time in the region. The long-range transport of pollutants was also evaluated using clustering analysis from back trajectories calculated from HYSPLIT.
- ***Source apportionment of PM2.5 using organic/inorganic markers and emission inventory evaluation in the East Mediterranean-Middle East city of Beirut by Fakhri N., Fadel M., Pikridas M., Sciare J., Hayes P.L., Afif C. (2023). Environmental Research, 223, 115446***; This paper sheds the light on the importance of adding organic molecular markers in source apportionment models like PMF, by comparing results of two source apportionment studies of the same data set in Greater Beirut Area (Lebanon) with and without organics. Moreover, implications on air quality are presented in light of a potency-mass PM2.5 analysis taking into consideration the environmental conditions of the EMME and the WHO air quality recommended values. Finally, an assessment of global and national emissions inventories has been conducted for the road transport sector in Lebanon showing that the global inventories underestimate Beirut road transport emissions by a factor of 15.
- ***Ubiquity of anthropogenic terpenoids in cities worldwide: Emission ratios, emission quantification and implications for urban atmospheric chemistry by Borbon, A., Dominutti, P., Panopoulou, A., Gros, V., Sauvage, S., Farhat, M., Afif, C., Elguindi, N., Fornaro, A., Granier, C., Hopkins, J.R., Liakakou, E., Nogueira, T., Corrêa dos Santos, T., Salameh, T., Armangaud, A., Piga, D., Perrussel, O. (2023). Journal of Geophysical Research – Atmospheres, 18, 7, e2022JD037566***; Terpenoids (isoprene and monoterpenes) are highly reactive VOC known for decades

for their biogenic origin. We discuss the nature and magnitude of their anthropogenic emissions by compiling and re-analyzing 14 data sets (including Lebanon) of in situ VOC observations collected over the last decade in contrasting urban areas from mid-latitudes to subtropical regions. The systematic presence of anthropogenic terpenoids in urban ambient air is shown, with a special role of traffic in developing countries.

- ***Brown carbon absorption and radiative effects under intense residential wood burning conditions in Southeastern Europe: New insights into the abundance and absorptivity of methanol-soluble organic aerosols by Paraskevopoulou, D., Kaskaoutis, D.G., Grivas, G., ... K. Oikonomou, E. Gerasopoulos, E., Mihalopoulos, N. Science of the Total Environment, 2023, 860, 160434***. This study examines the absorption properties of water- and methanol-soluble organic carbon (WSOC, MeS_OC) in a city (Ioannina, Greece) heavily impacted by RWB.
- ***Ambient carbonaceous aerosol levels in Cyprus and the role of pollution transport from the Middle East by Christodoulou, A., Stavroulas, I., Vrekoussis, M., Desservettaz, M., Pikridas, M., Bimenyimana, E., Kushta, J., Ivančič, M., Rigler, M., Goloub, P., Oikonomou, K., Sarda-Estève, R., Savvides, C., Afif, C., Mihalopoulos, N., Sauvage, S., & Sciare, J. (2023).*** Atmospheric Chemistry and Physics, 23(11), 6431–6456. https://doi.org/10.5194/acp-23-6431-2023; Collaboration with Aerosol d.o.o., a manufacturer of aethalometers. Source identification of organic pollution sources in Nicosia. Transported pollution and wood burning identified as major sources of pollution.