



**THE CYPRUS
INSTITUTE**

Research • Technology • Innovation

Recent developments on air pollution observation in the Eastern Mediterranean Middle East (EMME)



Prof. Jean Sciare

Director of the Energy Environment Water Research Centre
(EEWRC)



Cyprus
University of
Technology

Conference Room Senate House
30 Archbishop Kyprianos Str.
3036 Limassol

Tuesday
25 April 2017
4:00 p.m.

Outline

PART I : The Cyprus Institute

- General presentation of the Cyprus Institute
- The Energy Environment Water Research Center (EEWRC)

PART II : Air pollution in the E. Mediterranean

- Sources and impacts
- Air pollution research infrastructure

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OUR INSTITUTE – OVERVIEW



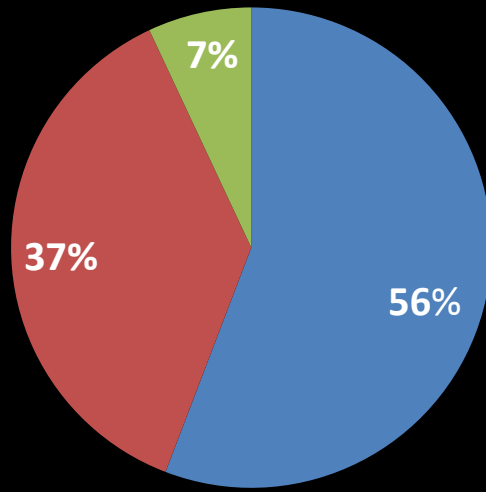
A research and educational institution suited to a **knowledge economy**, taking advantage of the Cyprus «**gateway**» niche.

A European institution, for the **Eastern Mediterranean** based in Cyprus.

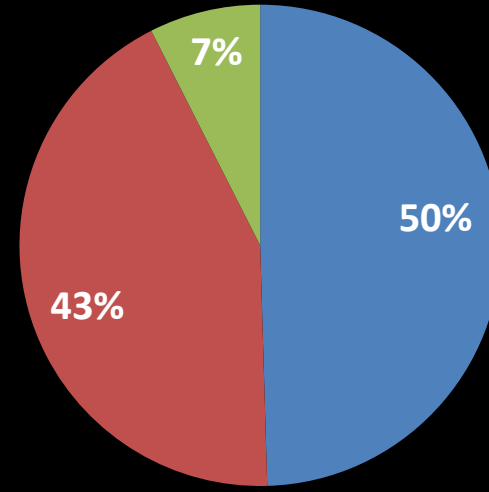
A non-governmental institution devoted to the **public benefit** and for **advancing peace and prosperity in the region**, using science and technology.

International in outlook

Nationality: All staff



Nationality: Research Staff



✓ **20 different nationalities**

✓ **An international environment cultivating excellence
(English spoken institute)**

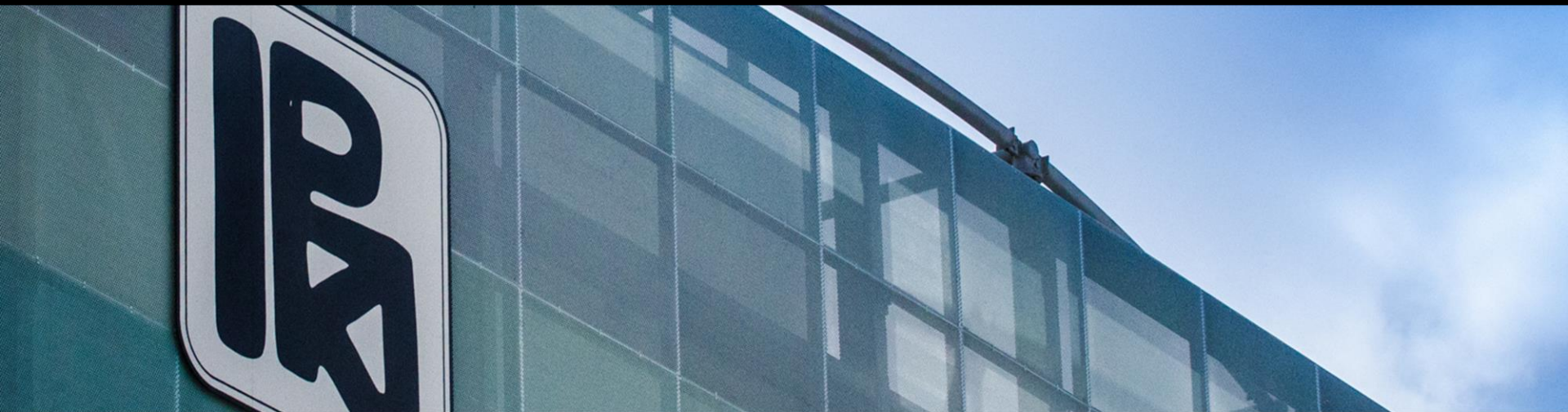
OUR RESEARCH CENTERS

Our 3
Fundamental
Building
Units

Energy, Environment & Water (**EEWRC**)

Science Technology in Archaeology & Culture (**STARC**)

Computation-Based Science & Technology (**CaSToRC**)



Science and Technology in Archaeology Research Center (STARC)



Active

12

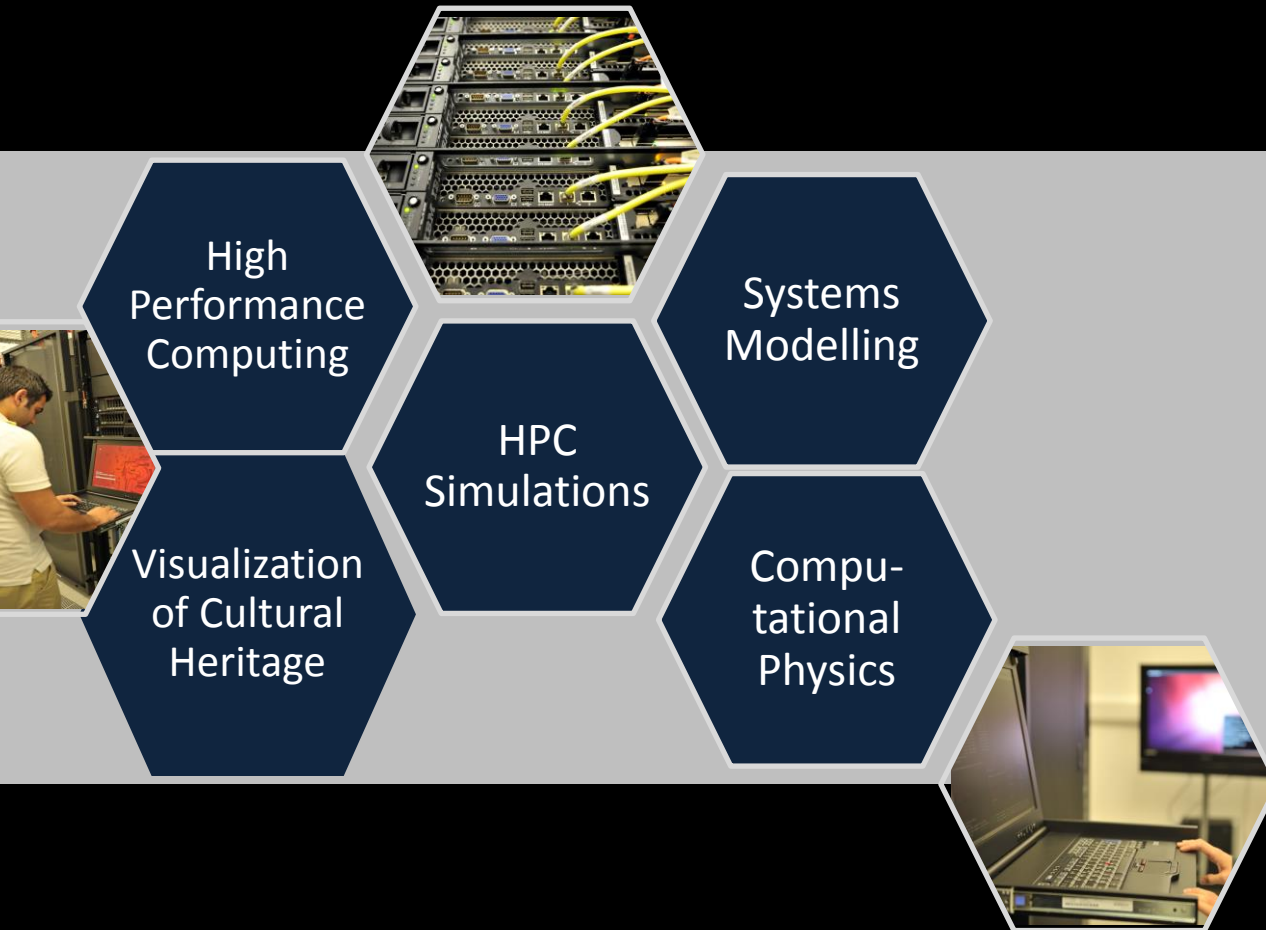
Projects

Founding

CENTRE DE
RECHERCHE
ET DE
RESTAURATION
DES MUSÉES
DE FRANCE

Partnership

Computation-based Science and Technology Research Center (CaSToRC):



Active

8

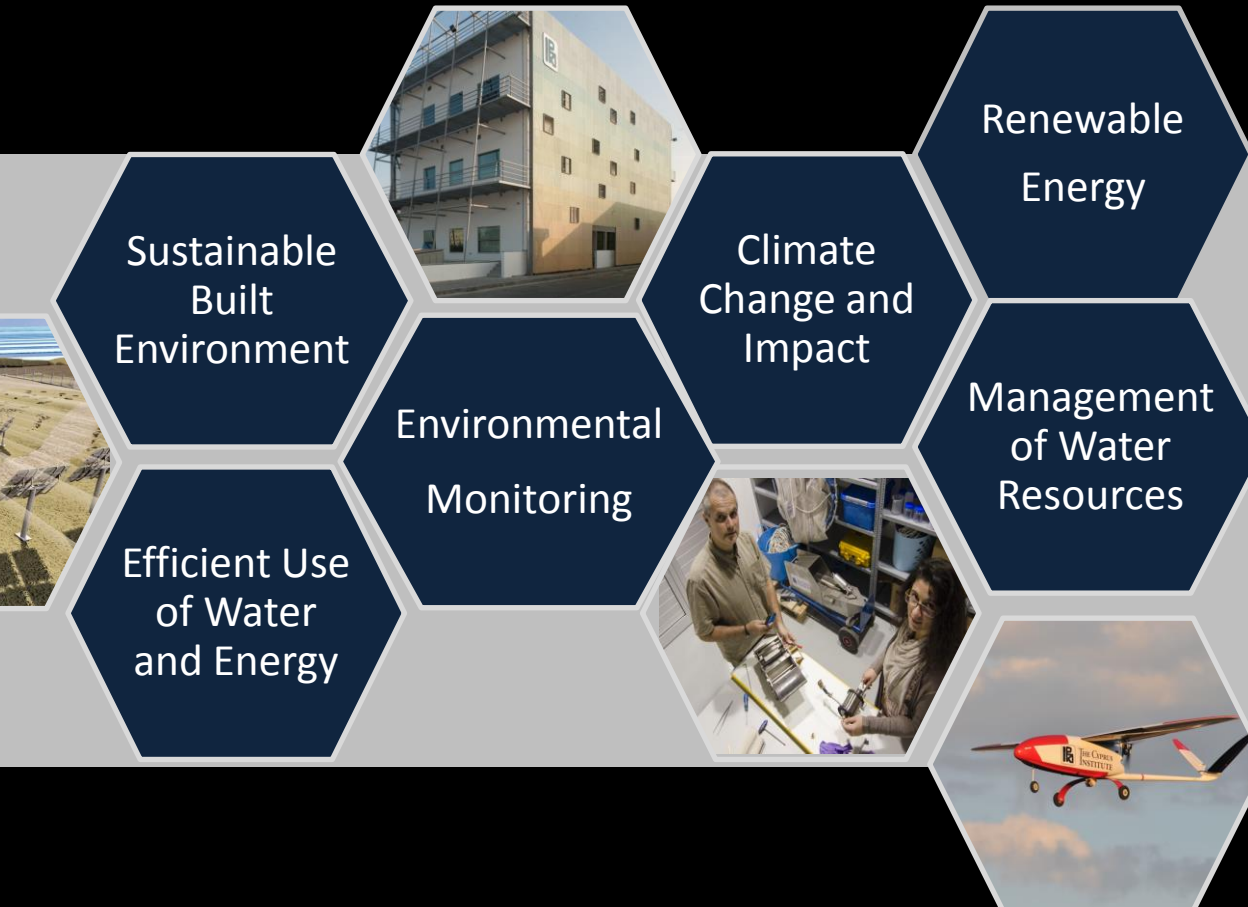
Projects

Founding



Partnership

Energy, Environment Water Research Center (EEWRC):



Active
19

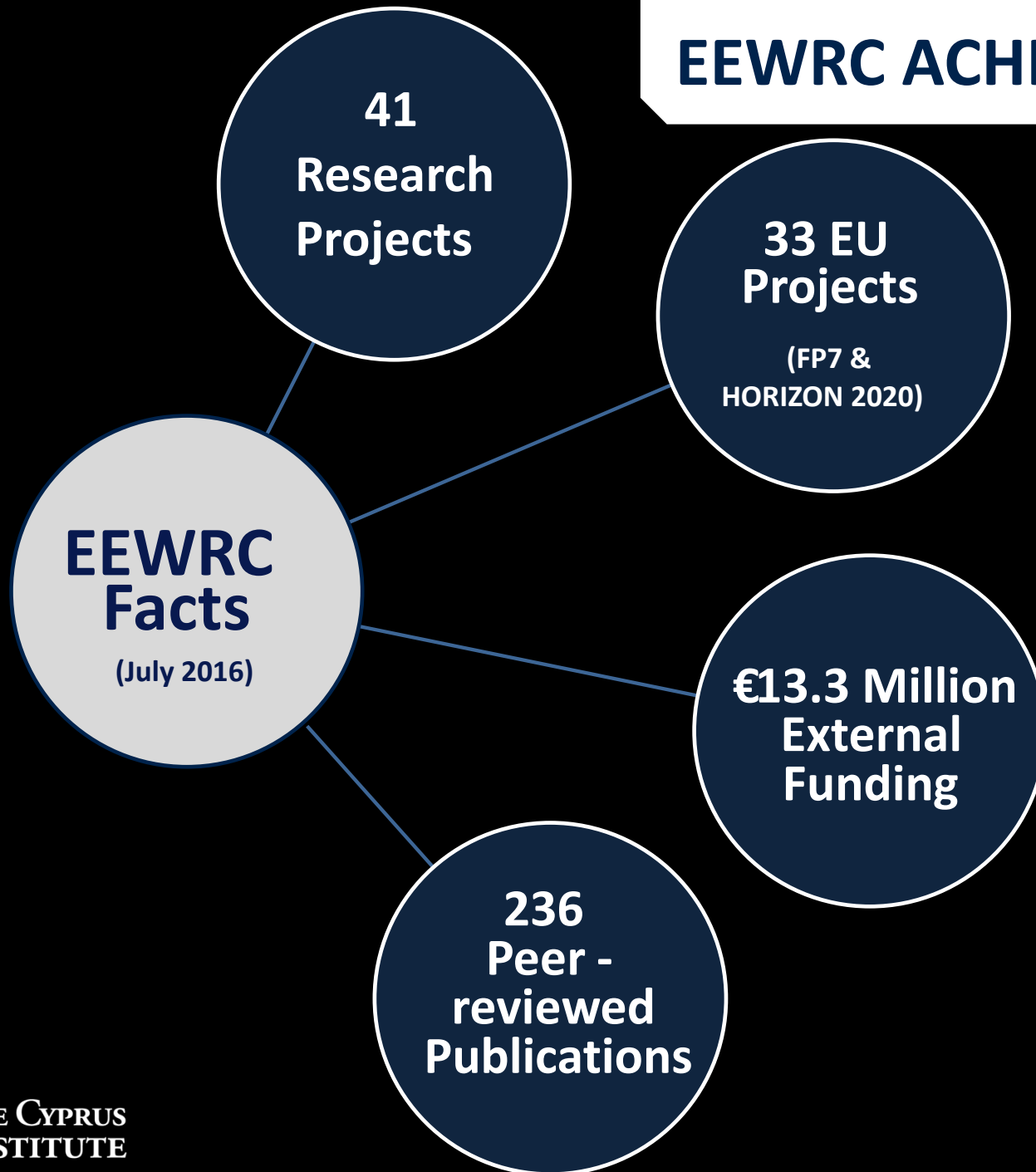
Projects



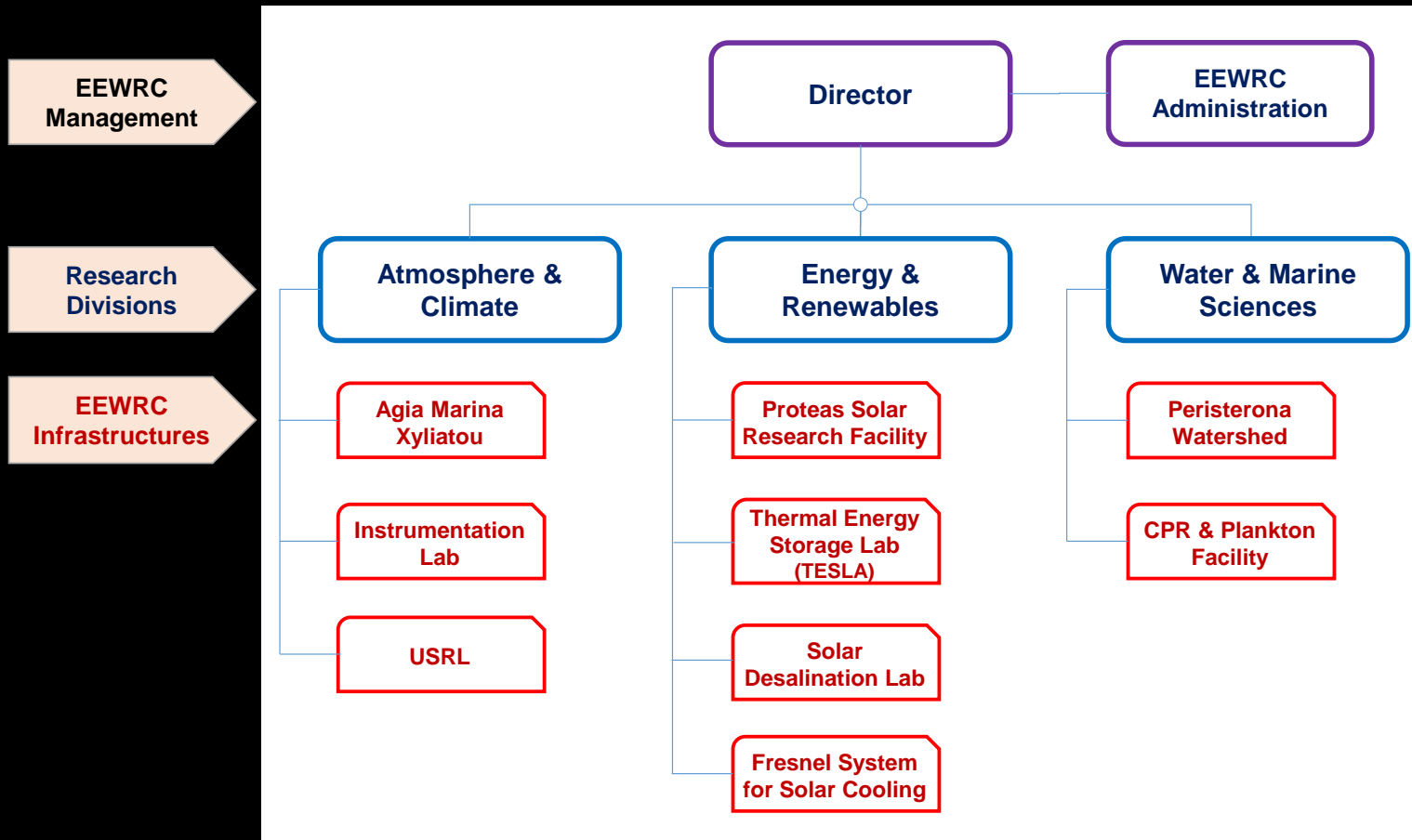
Massachusetts
Institute of
Technology

Partnership

EEWRC ACHIEVEMENTS



EEWRC STRUCTURE



- ✓ **3 Research Divisions**
- ✓ **9 EEWRC Infrastructures**

3

PhD Programs

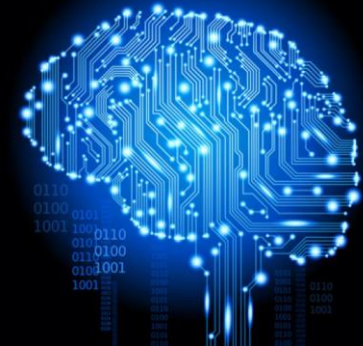
Science & Technology in
Cultural Heritage



Energy, Environment &
Atmospheric Sciences



Computational Sciences



- ❑ Three-year duration, organized in six semesters
- ❑ Language of instruction is English
- ❑ Directly linked to Cyl research activities
- ❑ Limited number of students of high caliber
- ❑ Fully accredited

Doctoral Program in Energy, Environment and Atmospheric Sciences

Doctoral students carry out research in Environmental and Atmospheric Science with an option to follow specialization in the following fields:

Solar Energy and Desalination

Climate Change and Impact

Environmental Research and Monitoring

Water Research & Management

Sustainability and Built Environment



Courses are taught and candidates are supervised mainly by faculty of the Energy, Environment and Water Research Center (EEWRC)

Educational Agreements

Joint/dual PhD degrees

- University of Illinois
- University Paris-Saclay
- University of Lund
- University of RWTH Aachen
- University of Wuppertal
- University of Rome “Tor Vergata”



Cross-registration

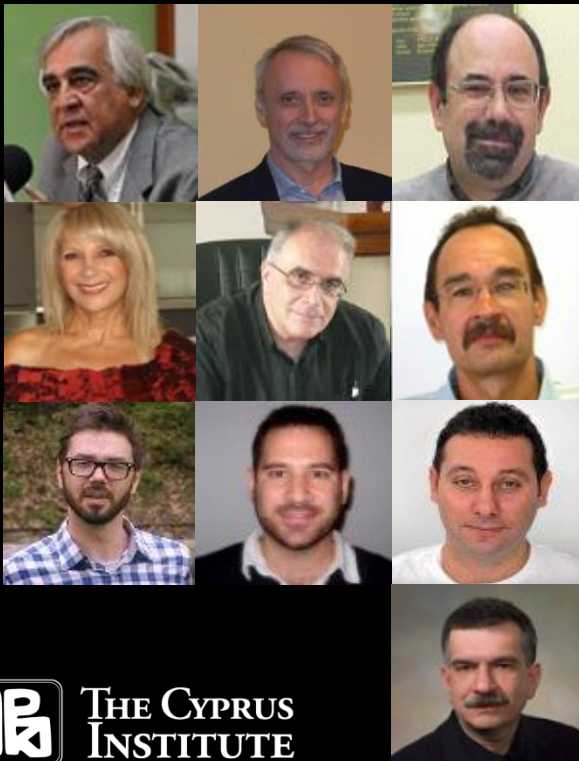
- University of Cyprus
- SISSA the International School for Advanced Studies

Energy & Renewables Division

Focusing on

- ✓ *Concentrated Solar Power (CSP)*
- ✓ *Co-generation of desalinated water*
- ✓ *Co-generation of desalinated water*
- ✓ *Built Environment*

Faculty



Post-doctoral



Graduates

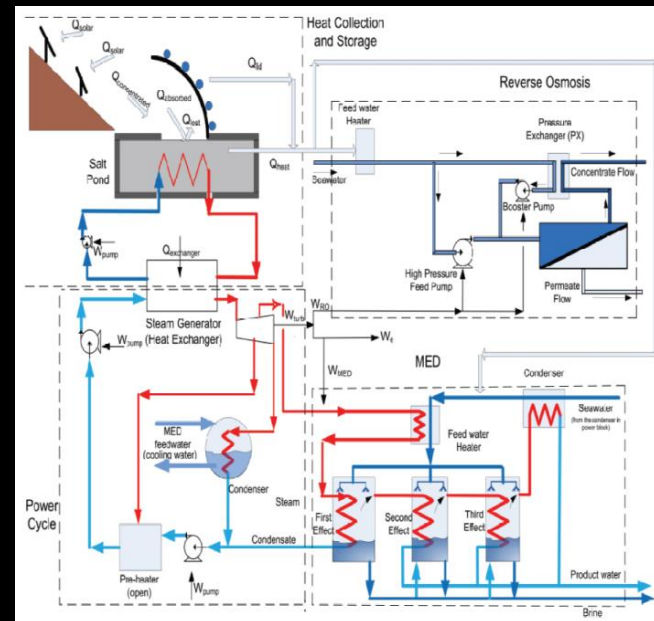
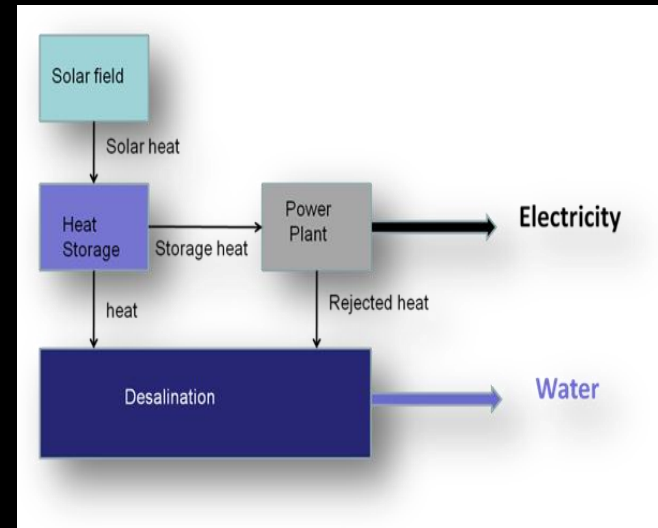


Project Coordination / Technical



The CSP-DSW study

- **The CSP-DSW Report[†]**
 - Co-generation of electricity and water from CSP
 - Techno-economic feasibility study
- **Report findings regarding solar field**
 - Heliostat-central receiver systems are most suitable for Cyprus
 - Propose the use of a novel receiver integrating thermal energy storage
 - Achieve co-generation through power generation and desalination cycles
- **Report findings regarding desalination**
 - Both **RO** & **MED** technologies are highly competitive
 - Advanced designs may give **MED** the advantage



- **RO:** Reverse Osmosis
 - Primary energy input: electrical
 - Energy consumption: 3-4 kWh/m³
- **MED:** Multiple Effect Distillation
 - Primary energy input: thermal
 - Energy consumption: 30-50 kWh/m³

The PROTEAS Facility

PROTEAS: Platform for Research, Observations and Technological Applications in Solar Energy

■ Overall objectives in CSP-DSW study context

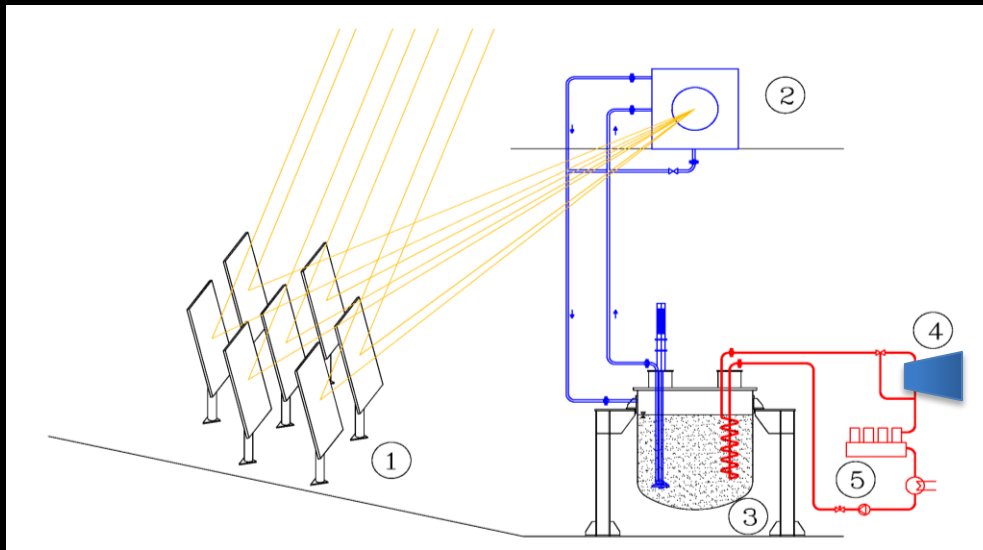
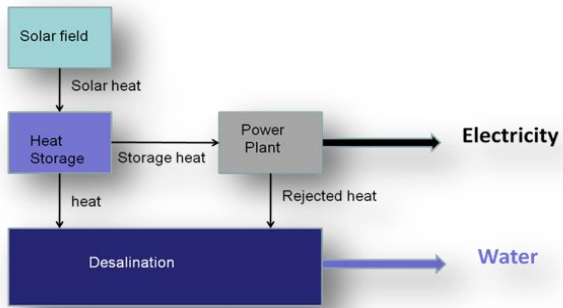
- Development, testing and verification of components and technologies
- Development of technology suitable for island or (grid) isolated communities

■ Solar harvesting and energy storage

- 50 heliostats, 5m² each, single facet design
 - 150 kW_{th} peak energy harvested from solar field
 - Thermal energy storage in solar salt (NaNO₃-KNO₃ – 60-40% b.w.)



Cogeneration of Electricity & Desalinated Sea Water



Aerial View of the PROTEAS Field Facility

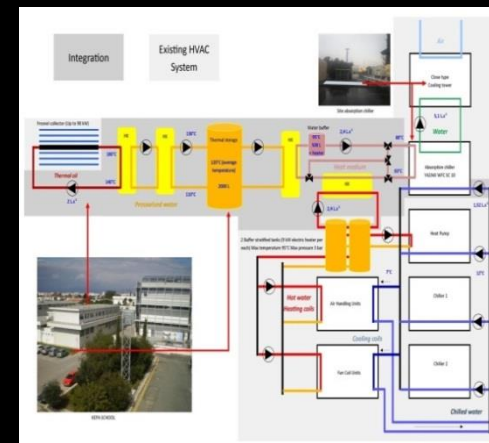
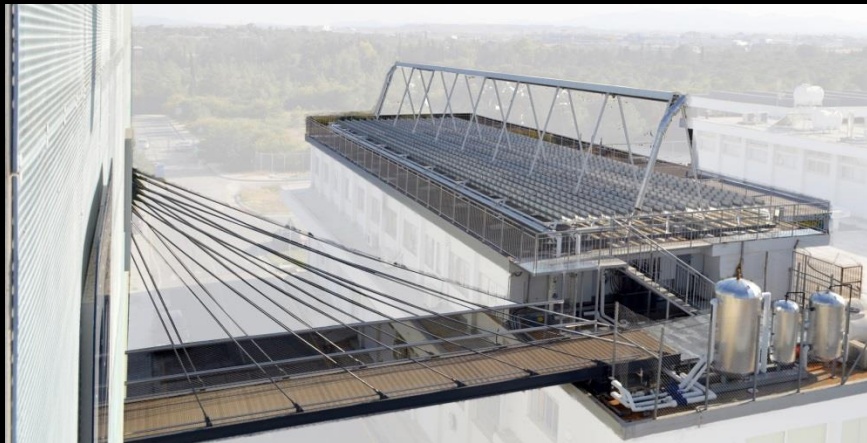


Linear Fresnel systems for Building HVAC

Solar Cooling/Heating of Buildings

Development of small scale solar-thermal district units for Mediterranean communities

- Linear Fresnel system for solar harvesting (thermal oil as heat medium, 186 m² reflective aperture area, 70 kw thermal power, 150 kWh storage)
- Thermal energy used for cooling/heating in summer/winter seasons
- System integrated in building HVAC system
- 35 kW cooling capacity absorption chiller



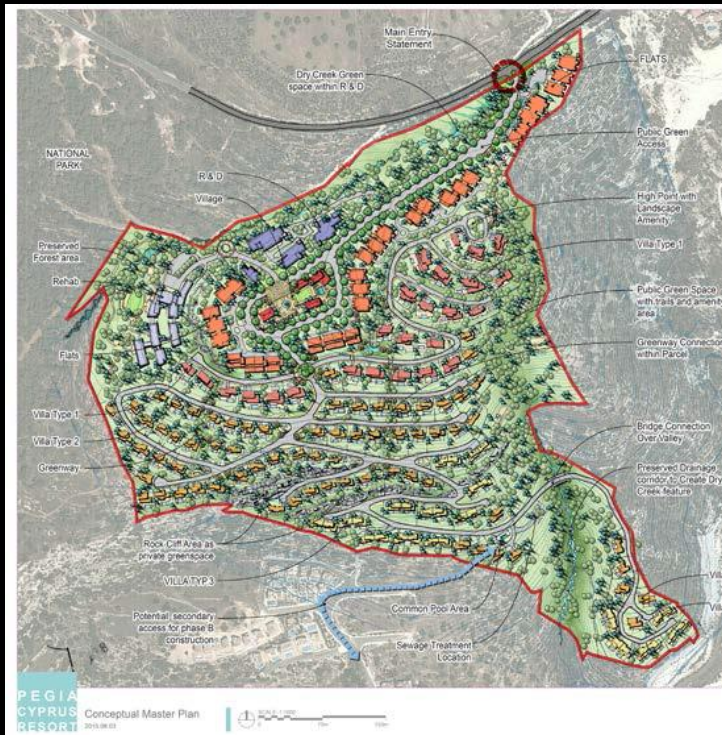
Zero-Plus Research Project

Achieving near Zero and Positive Energy Settlements in Europe using Advance Energy Technology

Cyprus Partners in the Project: Cyprus Institute, Aetheria Heights Development

Cyprus Case Study

Location: Peyia, Pafos District



Water & Marine Sciences Division

Focusing on

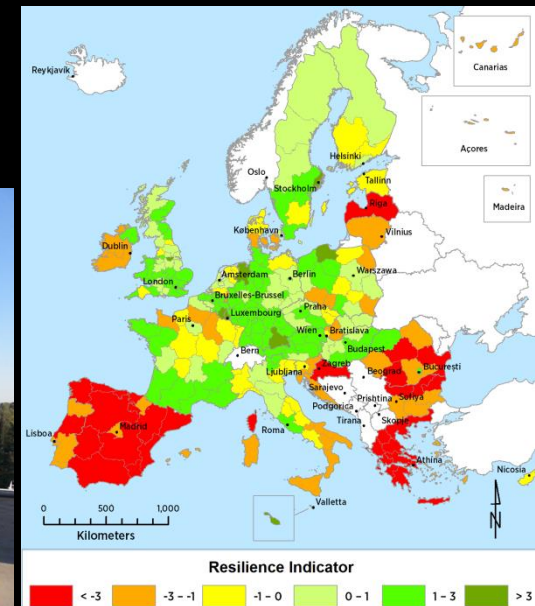
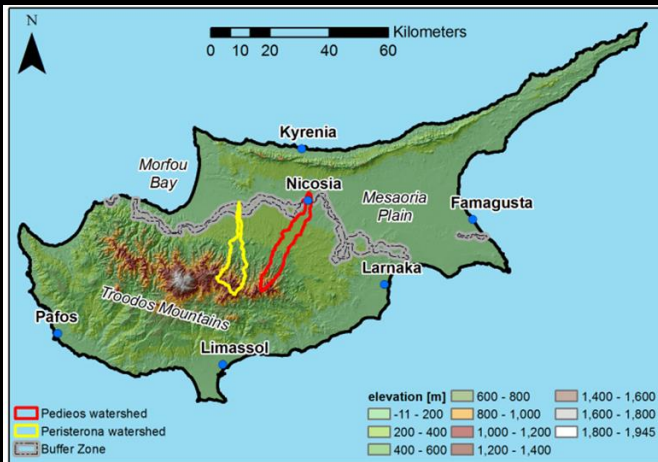
- ✓ *Hydrologic & environmental monitoring & modeling*
- ✓ *Water & natural resource management technologies & policies*
- ✓ *Understanding of shallow and deep-water marine ecosystems*



**2 Faculty, 1 Associate Research Scientist, 2 Post-docs,
4 PhD Students / Research Assistants, 1 part-time PhD Student
1 Research Affiliate**

Water and Natural Resource Management Research

- Hydrologic and environmental monitoring and modeling to improve our understanding of hydrologic processes
- Development and evaluation of water and natural resource management technologies, climate adaption options, and policies



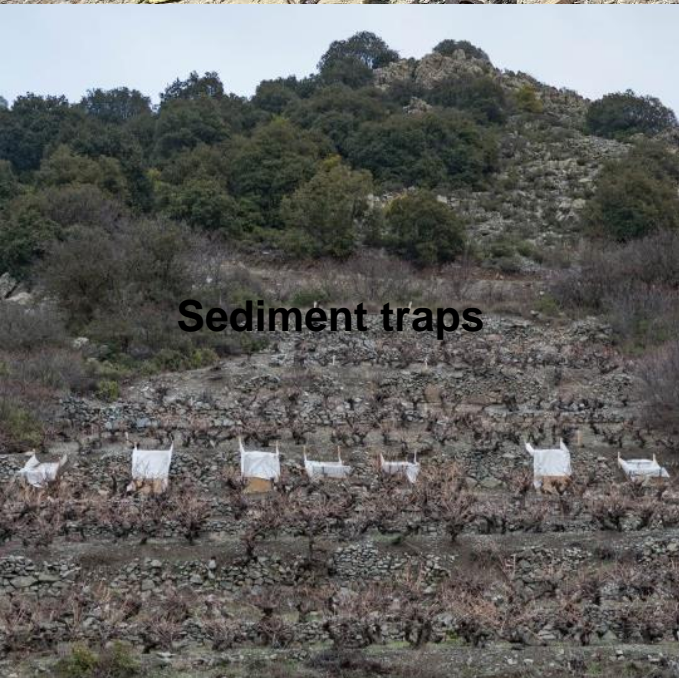
Hydrologic monitoring



Meteorology



Groundwater recharge



Sediment traps



Streamflow

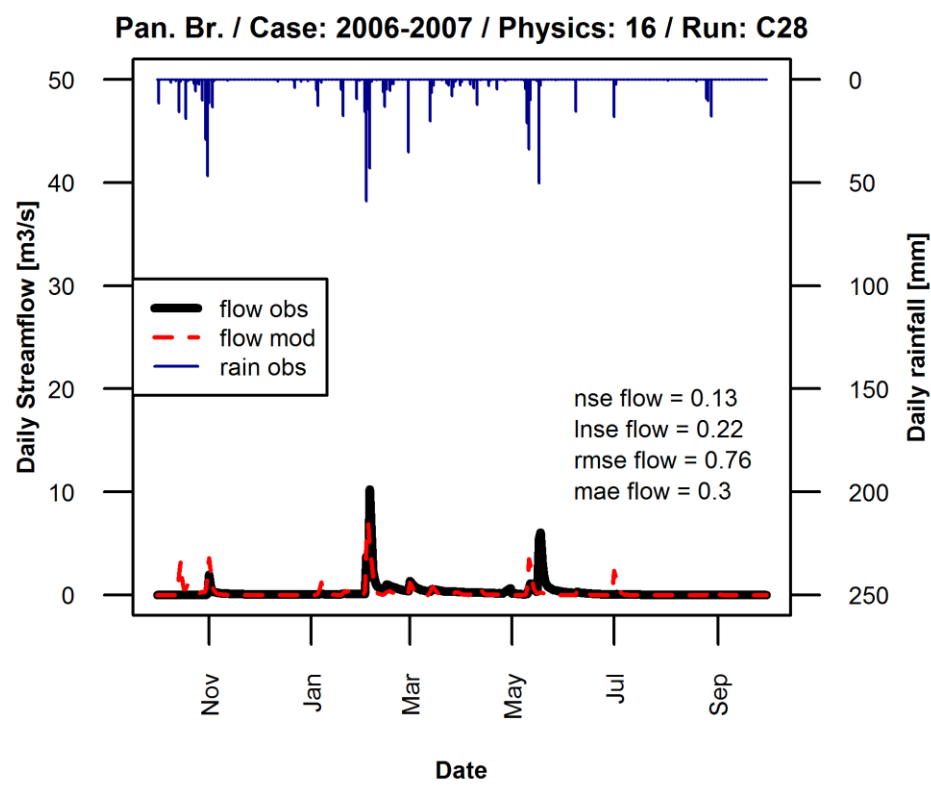


Forest water dynamics

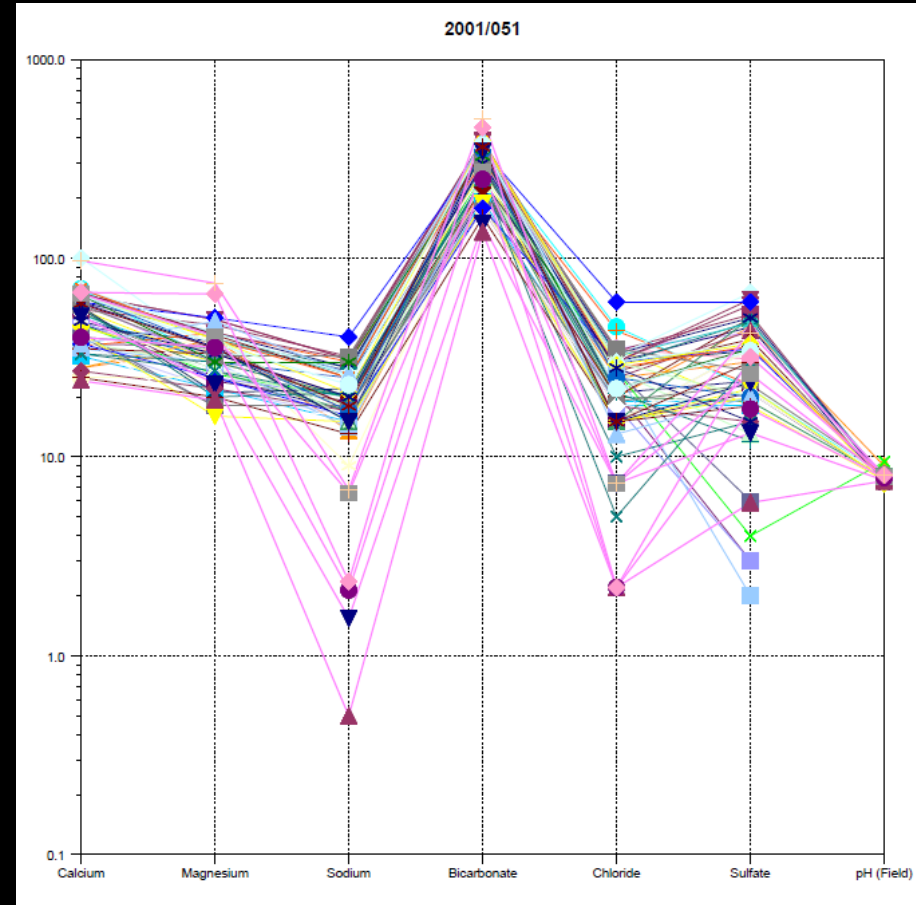


Hydrologic modelling

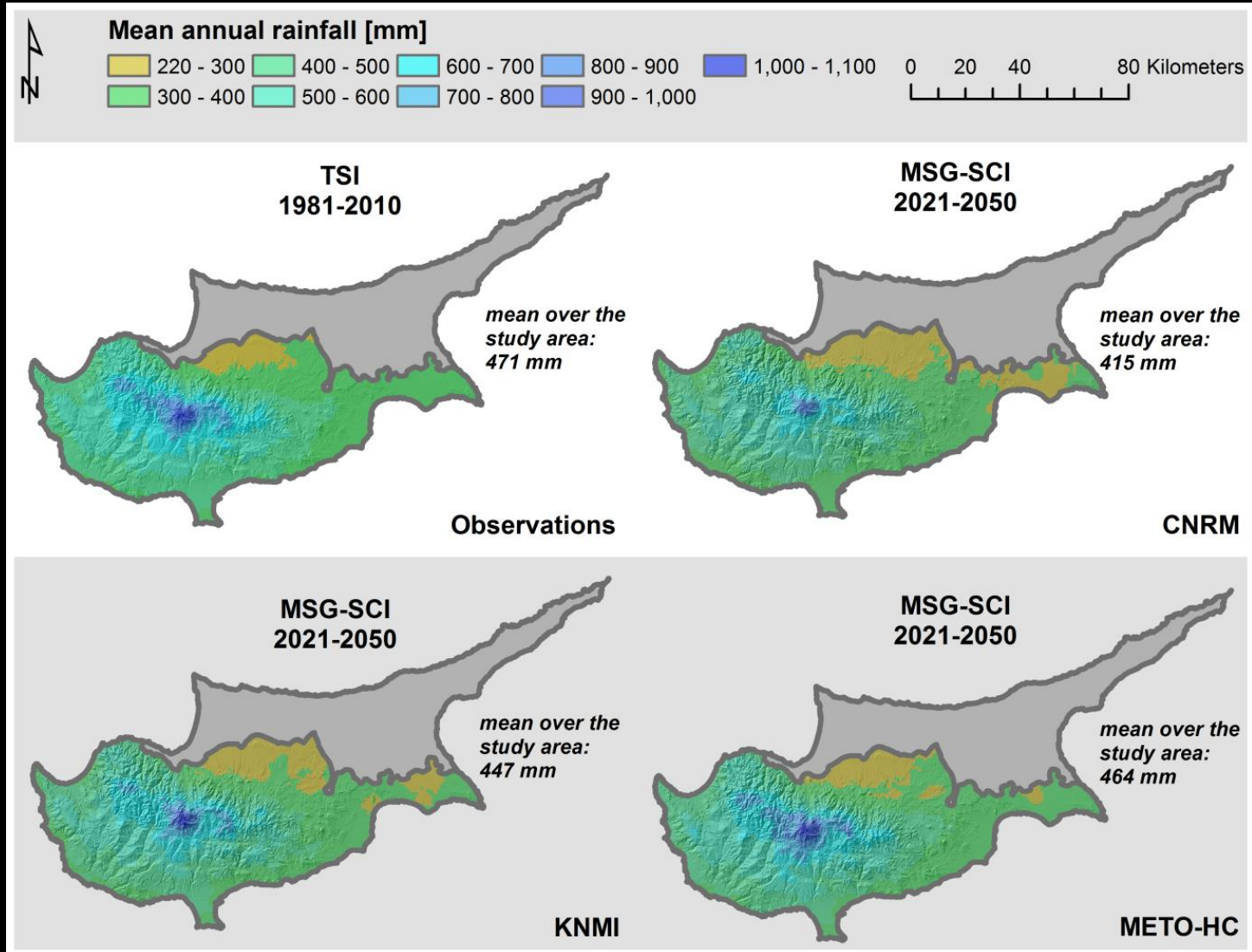
Coupled atmospheric and hydrologic modelling with WRF-Hydro



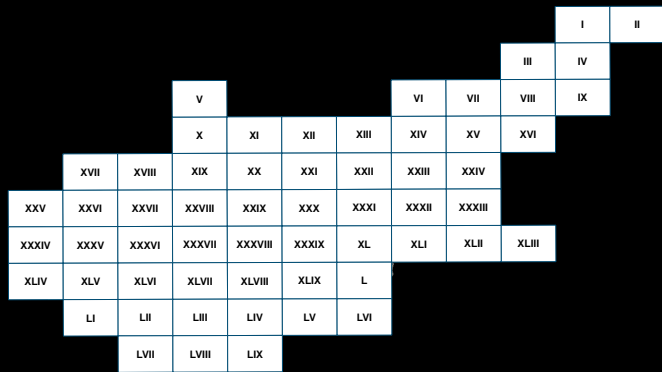
Hydrogeochemistry of Troodos Groundwater with Freeqc



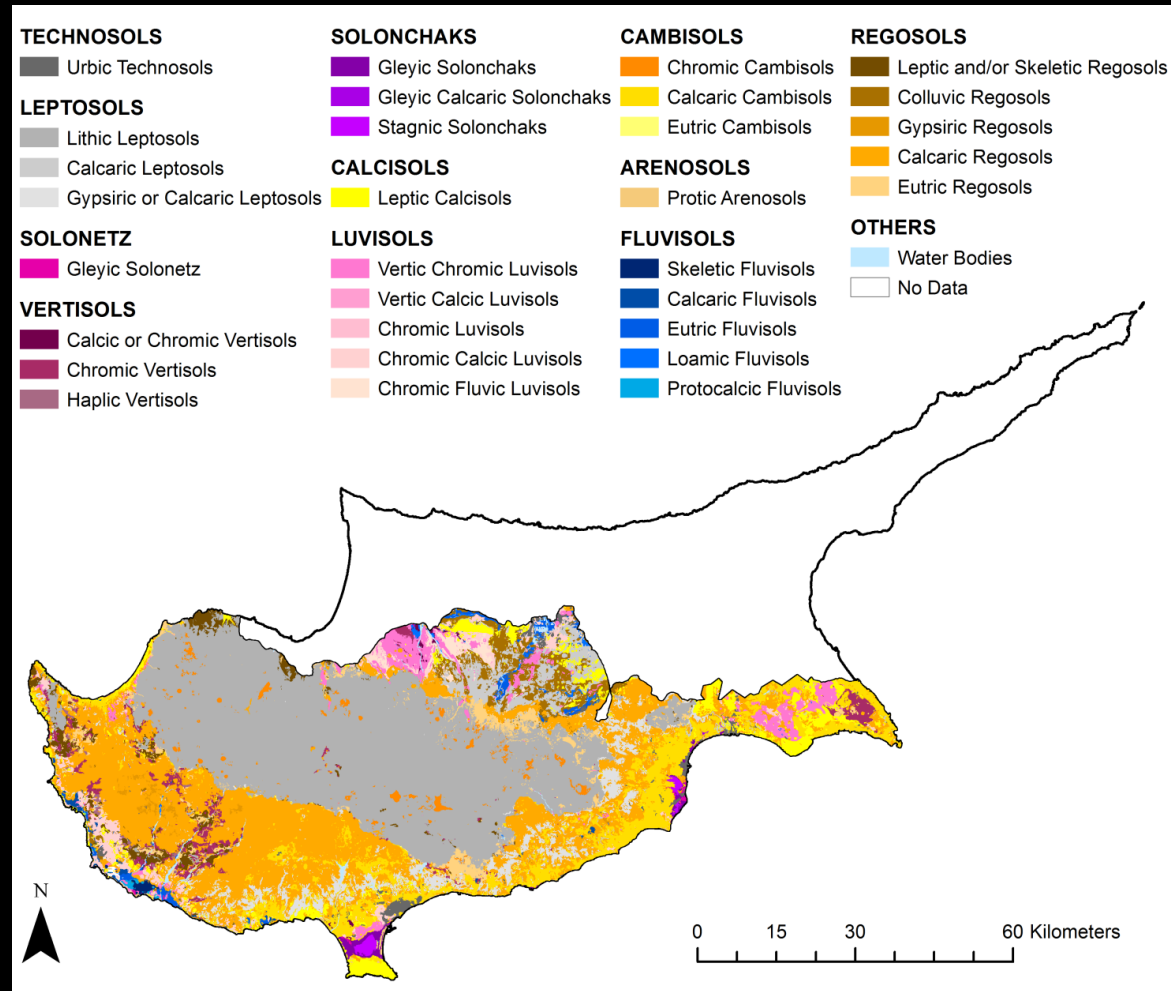
Development of 1-km gridded climate data sets for Cyprus and statistical downscaling for climate projections



Spatial data modelling: new high resolution digital soil map



Machine learning technique (Random Forest), using 10 high resolution soil maps and 10 environmental co-variates



Transdisciplinary research with stakeholders



Improving irrigation with wireless sensor networks

New PhD position open now: <http://www.cyi.ac.cy/education>



Atmosphere & Climate Division

Focusing on

- ✓ *Anthropogenic changes of gases & aerosols in the atmosphere*
- ✓ *Climate change, weather extremes, air pollution*
- ✓ *Environmental health*

Faculty (7)



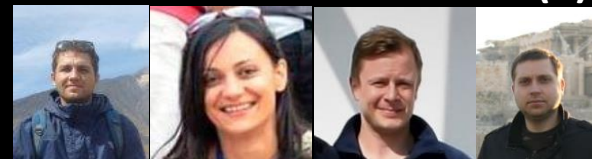
Adjunct Faculty / Affiliate (5)



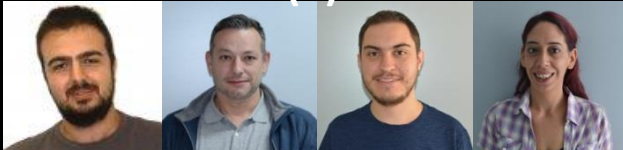
Associate Research Scientist (3)



Post-doctoral fellows (4)



PhD Students (3)



Research Assistants (2)



UAV pilots / Engineers / Interns (9)



Project Manager (1)



Research Infrastructure

Facility for Chemical Analysis (FCA)



Cyprus Atmospheric Observatory (CAO)



Unmanned Systems Research Laboratory (USRL)



Outline

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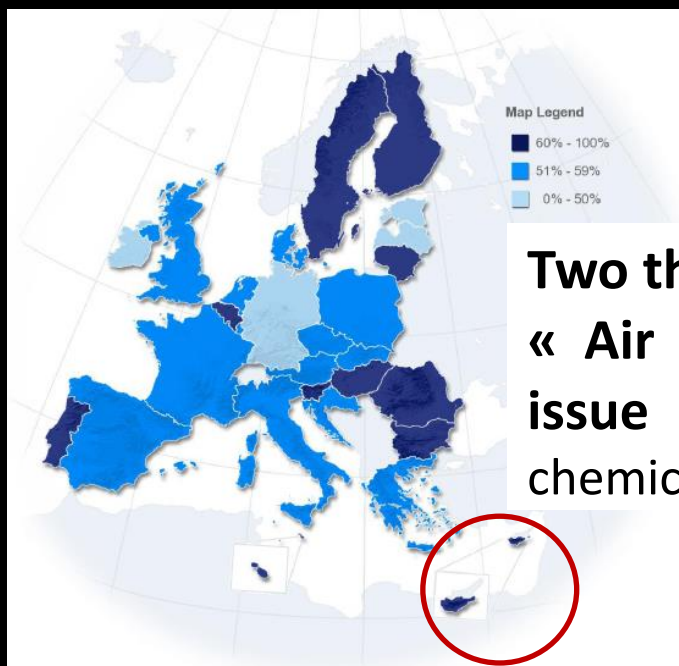
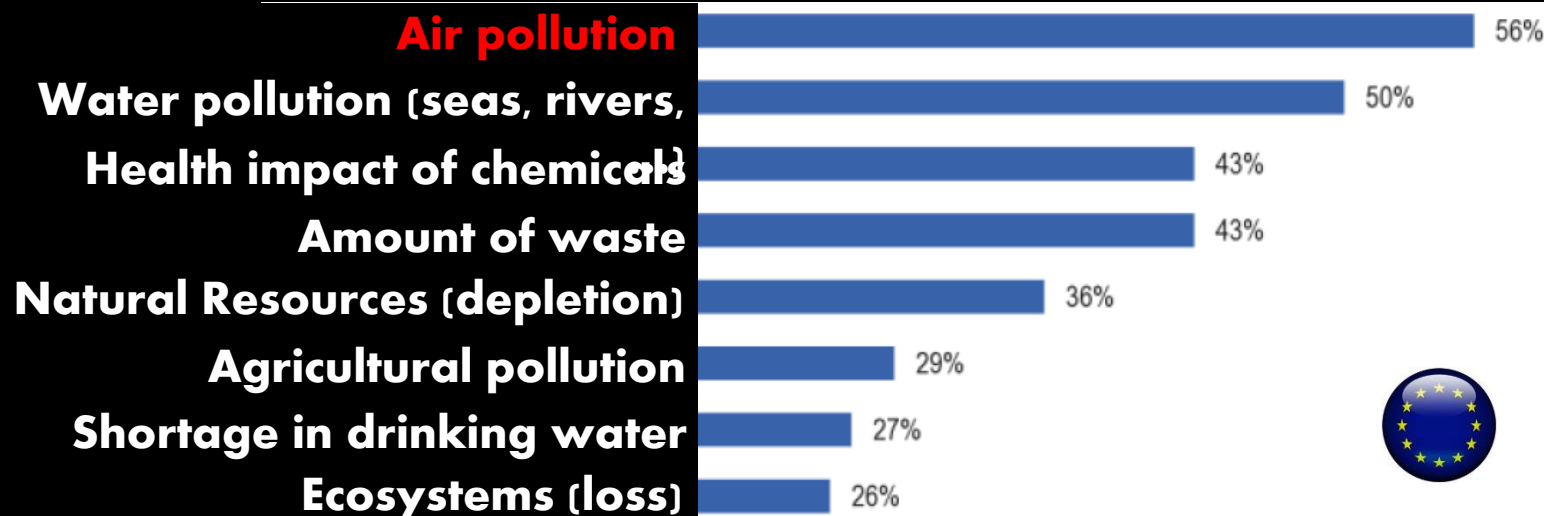
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PART II : Air pollution in the E. Mediterranean

- Sources and impacts
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Air pollution :

First environmental concern of EU citizens & Cypriots



Source : Adapted from « Special Eurobarometer 416 (2014), Attitudes of European citizens towards the environment »

Two third of the Cypriot population ranks « Air pollution » as the first Environmental issue before water pollution, health impact of chemicals, and shortage in drinking water

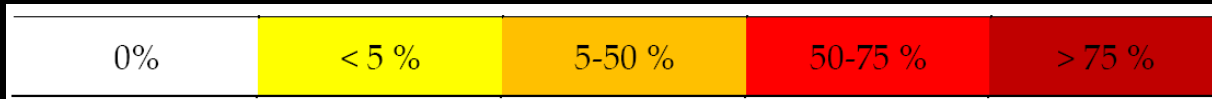
Air pollution :

**100% of the Cypriot population
exposed to air pollution (aerosols) above EU limit values**

Urban population exposed to air pollutant concentrations above the EU air quality objectives (2010-2012)

Cyprus	EU reference value	Exposure estimate (%)		
		2010	2011	2012
PM ₁₀	day (50 µg/m ³)	100.0	100.0	100.0
O ₃	8-hour (120 µg/m ³)	0.0	0.0	0.0
NO ₂	year (40 µg/m ³)	0.0	0.0	0.0

fraction of urban population exposed to concentrations above the reference level



European Environment Agency



Source: Air pollution fact sheets 2014

Air pollution : HEALTH IMPACT

8,000 Years of life lost

attributable to PM_{2.5}, O₃ and NO₂ exposure in 2012 in Cyprus

Country	PM _{2.5}			O ₃			NO ₂		
	Annual mean	YLL	YLL/10 ⁵ inhabitants	SOM035	YLL	YLL/10 ⁵ inhabitants	Annual mean	YLL	YLL/10 ⁵ inhabitants
Cyprus	25.0	8 000	729	8 369	500	47	9.42	0	0



Source: EEA Air pollution 2015 Report

Air pollution : ECONOMIC IMPACT

857 millions US\$ of Economic cost of deaths from air pollution (outdoor and indoor) in Cyprus

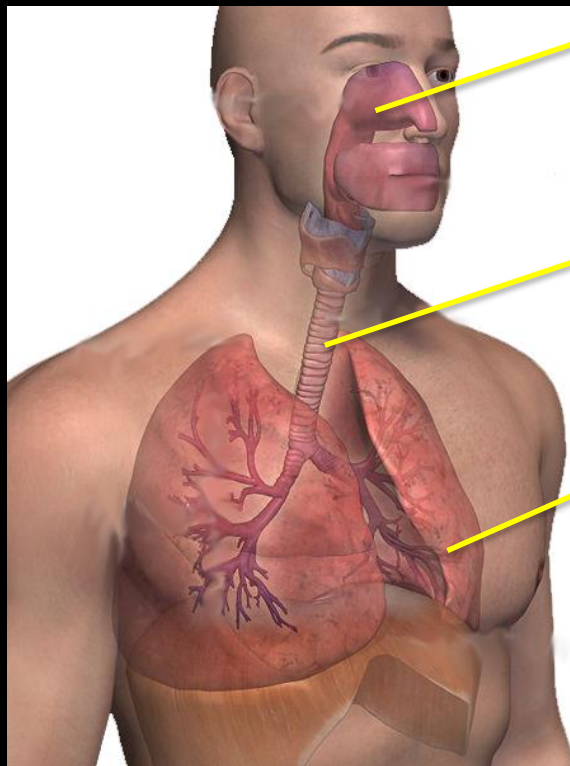
Country ^a	Economic cost of deaths from air pollution	
	US\$ millions	Percentage of GDP (at purchasing power parity)
Cyprus	857	3.3



Source: WHO European Region (2010)

Expenditure for R&D (% GDP) = 0.48% for Cyprus (2010)

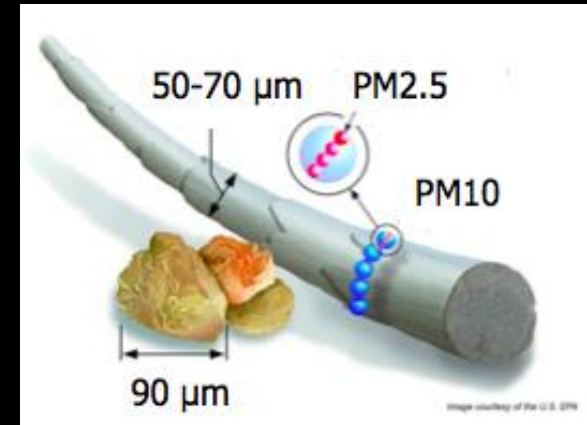
Air pollution : HEALTH IMPACT



Upper Respiratory System
($> PM_{10}$)

Trachea + Bronchus
($PM_1 - PM_{10}$)

Alveoli
($< 50 \text{ nm}$)



LETTER

doi:10.1038/nature15371

The contribution of outdoor air pollution sources to premature mortality on a global scale

J. Lelieveld^{1,2}, J. S. Evans^{3,4}, M. Fnais⁵, D. Giannadaki² & A. Pozzer¹

Assessment of the global burden of disease is based on epidemiological cohort studies that connect premature mortality to a wide range of causes¹⁻⁵, including the long-term health impacts of ozone and fine particulate matter with a diameter smaller than 2.5 micrometres ($PM_{2.5}$). It has proved difficult to quantify premature mor-

GBD⁶ we also include desert dust (which is largely natural) with $PM_{2.5}$, hence strictly speaking we assess the effects of atmospheric composition.

The air quality guidelines of the World Health Organization (WHO) and national regulatory policies are based on exposure res-

... we calculate that outdoor air pollution, mostly by $PM_{2.5}$, leads to 3.3 million premature deaths per year worldwide ...

being even more dominant if carbonaceous particles are assumed to be most toxic. Whereas in much of the USA and in a few other countries emissions from traffic and power generation are important, in eastern USA, Europe, Russia and East Asia agricultural emissions make the largest relative contribution to $PM_{2.5}$, with the estimate of overall health impact depending on assumptions regarding particle toxicity. Model projections based on a business-as-usual emission scenario indicate that the contribution of outdoor air pollution to premature mortality could double by 2050.

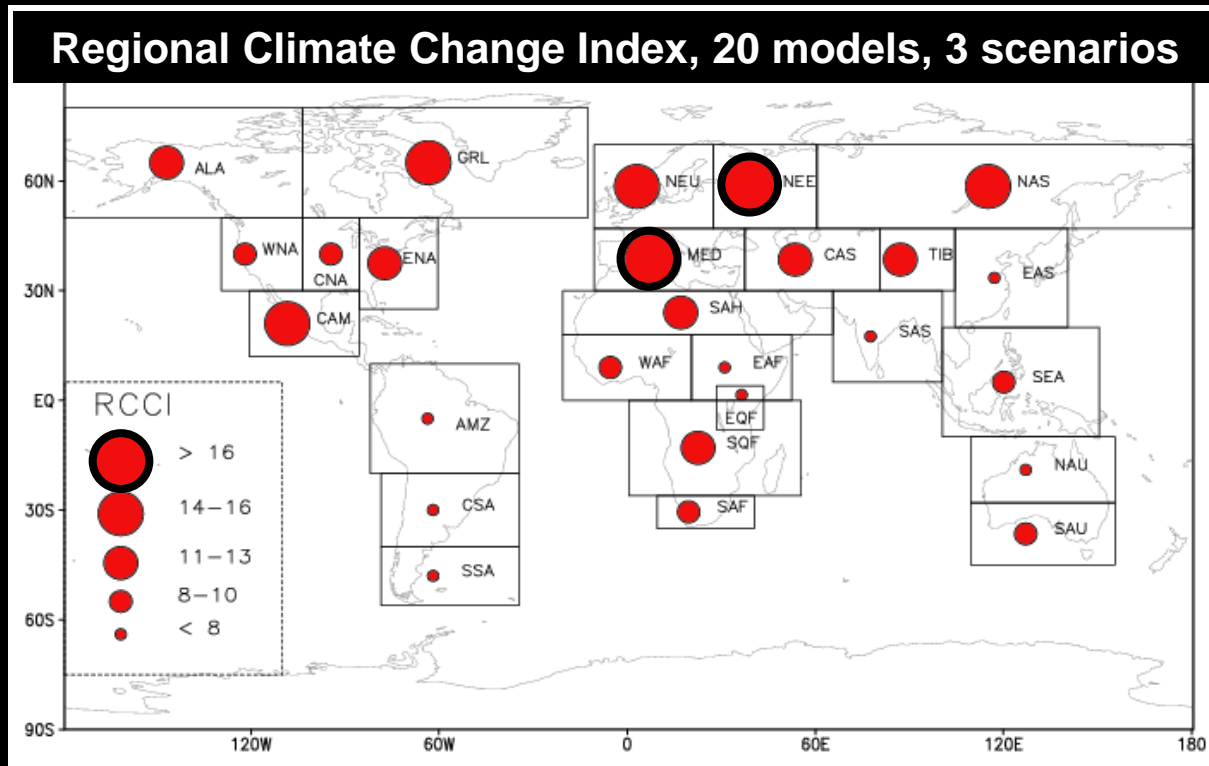
investigations where these sources and components were likely to be measured consistently^{2,6,7}. While the evidence for differential toxicity is far from conclusive, we conducted a secondary analysis assuming that carbonaceous $PM_{2.5}$ is five times more toxic than inorganic particles, though maintaining the same overall health impact of $PM_{2.5}$.

We have calculated premature mortality linked to CEV, COPD, IHD and LC for adults ≥ 30 years old, and ALRI for infants < 5 years old (Table 1 and Extended Data Tables 1 and 2). Our estimate of the global $PM_{2.5}$ related mortality in 2010 is 3.15 million people with a 95% confidence interval (CI95) of 1.52-4.60 million. The main causes are CEV

✓ The surface area of human lungs in contact with ambient air is equivalent to the superfcy of a tennis court

Climate Change:

The Mediterranean: A major climate Hot Spot region



Source: Giorgi (2006)

Climate-Exodus Expected in the Middle East and North Africa

Part of the Middle East and North Africa may become uninhabitable due to climate change

J. Lelieveld, et al., Strongly increasing heat extremes in the Middle East and North Africa (MENA) in the 21st century. *Climatic Change*, 2016
www.cyl.ac.cy

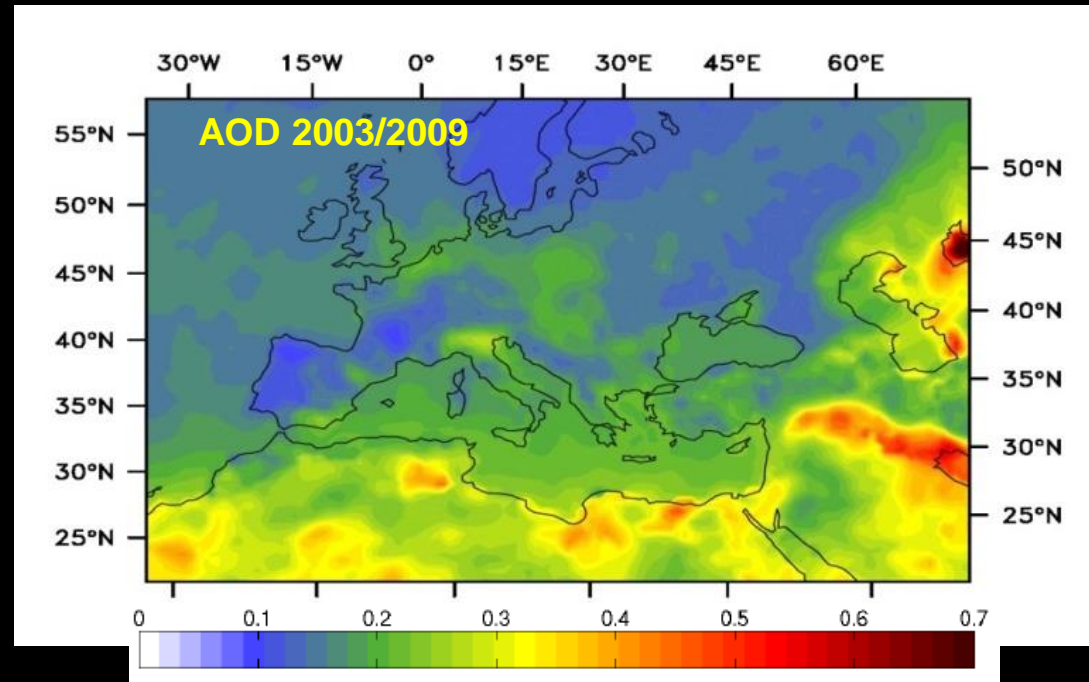


Why remote sensing observations are not enough?



Remote Sensing observations

- + High spatial coverage
- Poor precision / specificity



Human made emissions (climate change and air pollution)



In-situ observations

- + High precision / specificity
- Poor spatial coverage

Natural emissions



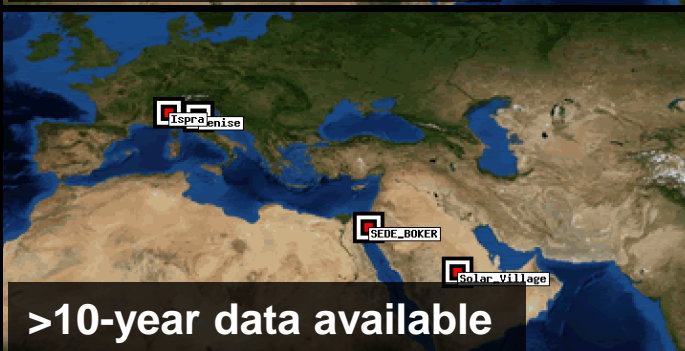
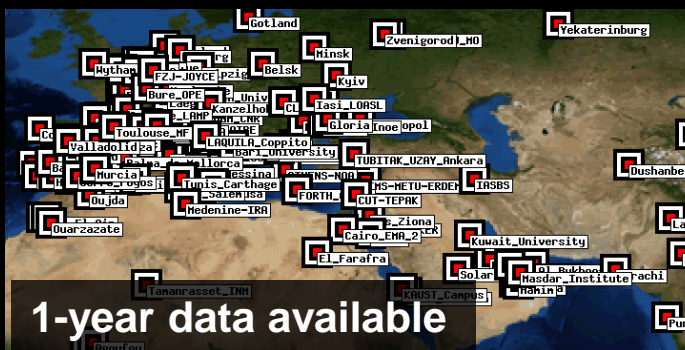
Atmospheric Networks: What are the challenges?



World Meteorological Organisation



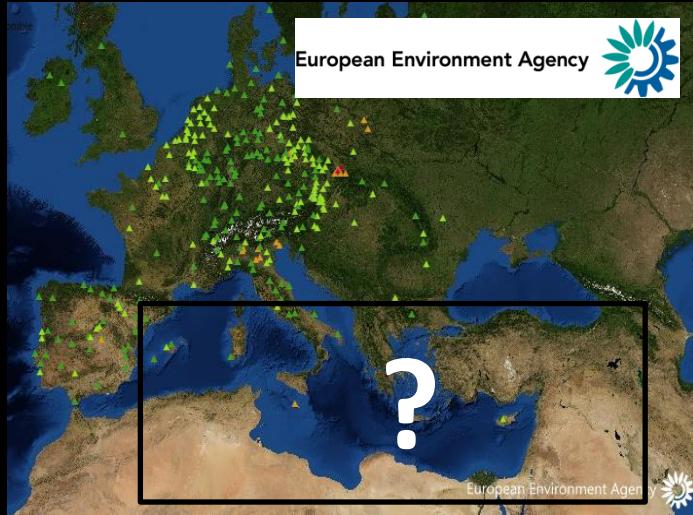
Many WMO-GAW stations ...
... But few are reporting data !!!



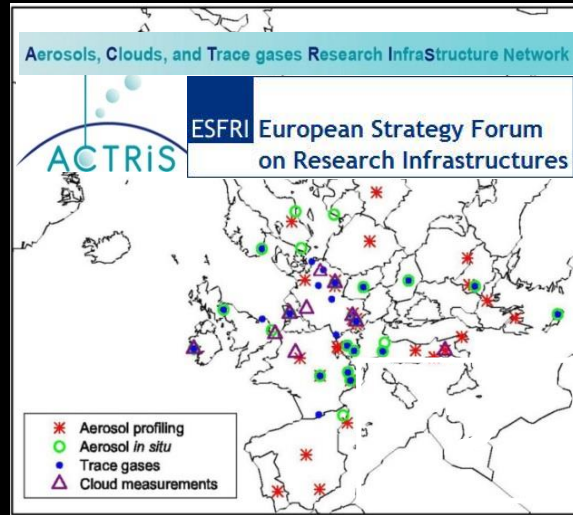
Many AERONET stations ...
... But few have long-term observations!!!

Atmospheric Networks: What are the challenges?

Air Quality



Aerosols/Clouds/Reactive gases

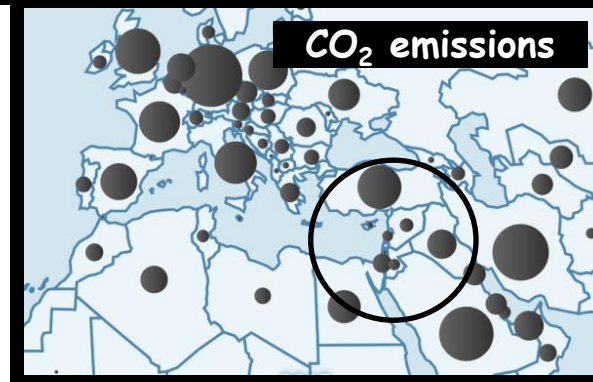
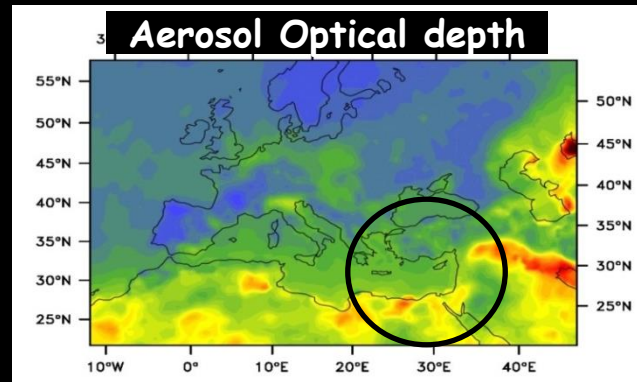
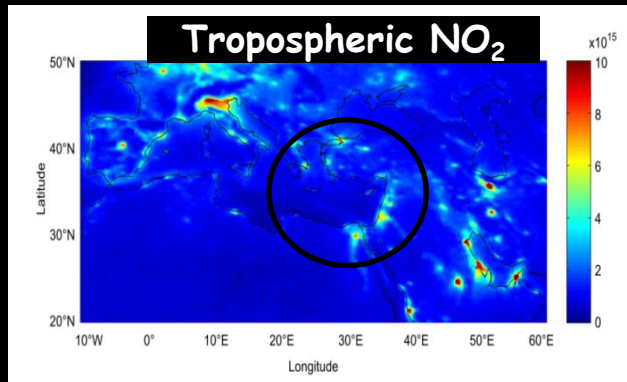


Greenhouse gases



Atmospheric networks well structured in Europe ...

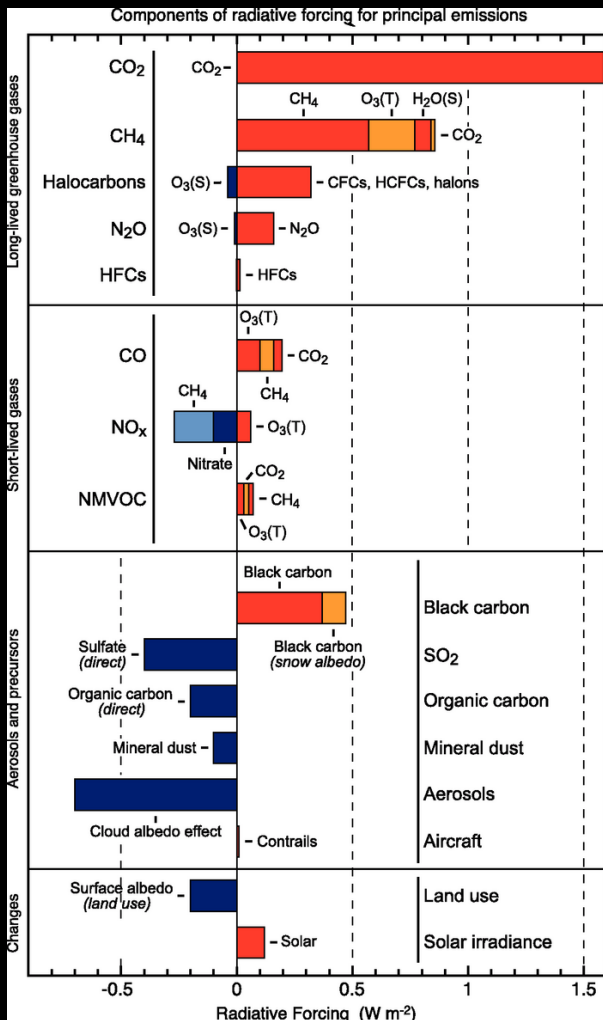
... But missing in neighboring countries (MENA region)



Although atmospheric emissions/pollution are also very high in the MENA !

Climate Change & Air pollution monitoring strategy

Long-term & high quality atmospheric observations part of EU/World Research Infrastructure at remote site in Cyprus representative of the regional pollution



GREENHOUSE GASES

(Long-lived direct emissions)
(CO₂, CH₄, CFCs, N₂O)

GREENHOUSE GASES

(emitted from short lived gases)
(CO, NO_x, NMVOC)

AEROSOLS warming AEROSOLS cooling

(Chemical/Optical/Physical properties)

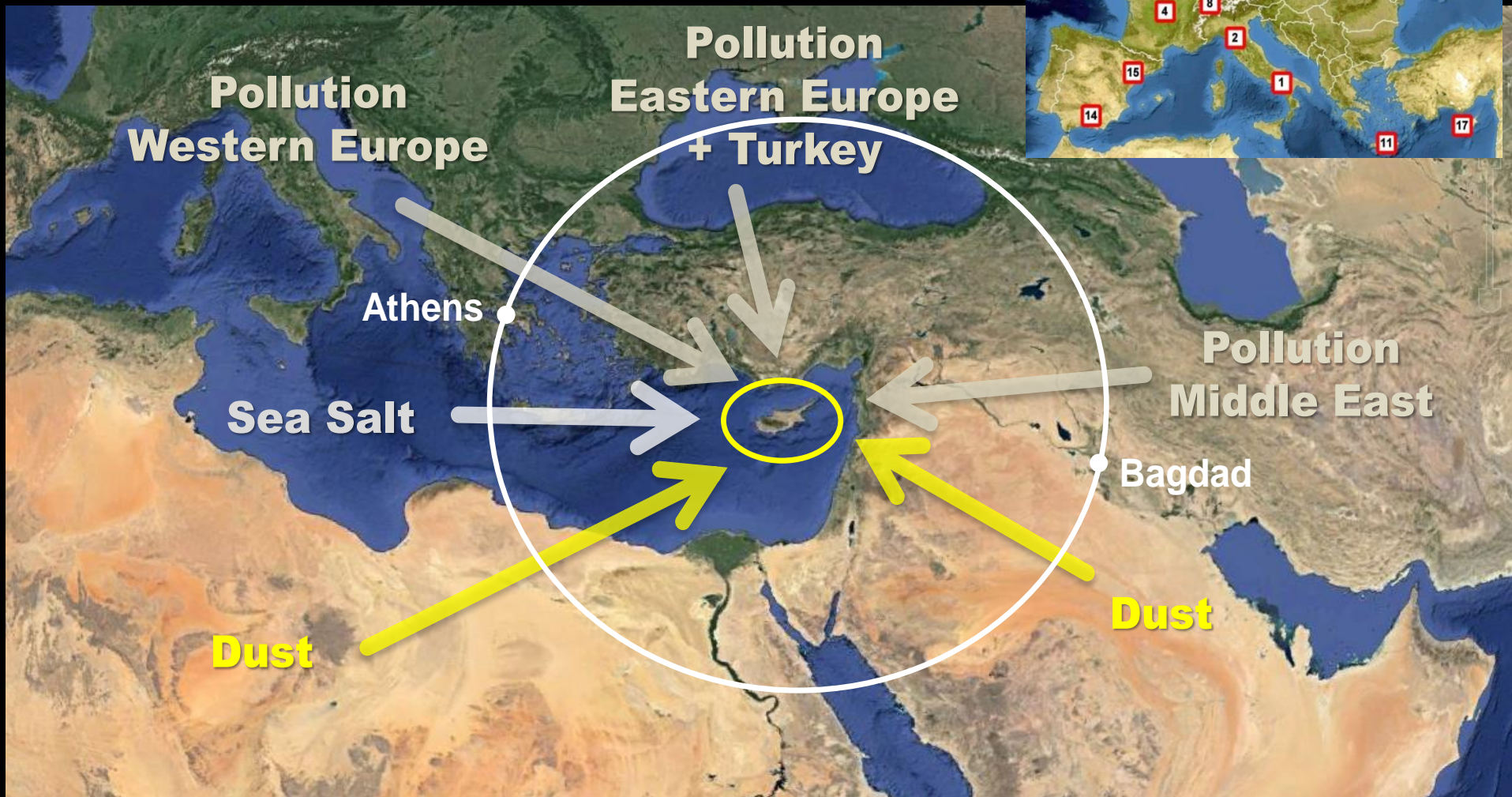
EU – World
Network

National
Partners



The Cyprus Atmospheric Observatory (CAO)

National facility to monitor
air pollution and climate change



The Cyprus Atmospheric Observatory (CAO)

In collaboration with



National facility to monitor
air pollution and climate change



AGIA MARINA XYLIATOU:

CAO “Cyprus Rural background”

CAVO GRECO :

CAO “Early warning” station for Middle East Air pollution

TROODOS:

CAO “Free troposphere” observatory

NICOSIA:

CAO “Urban pollution”

The Cyprus Atmospheric Observatory (CAO)

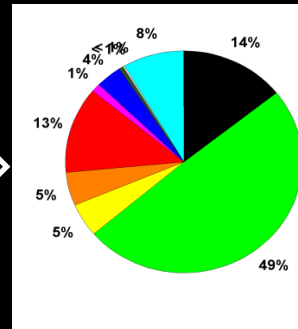
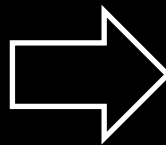
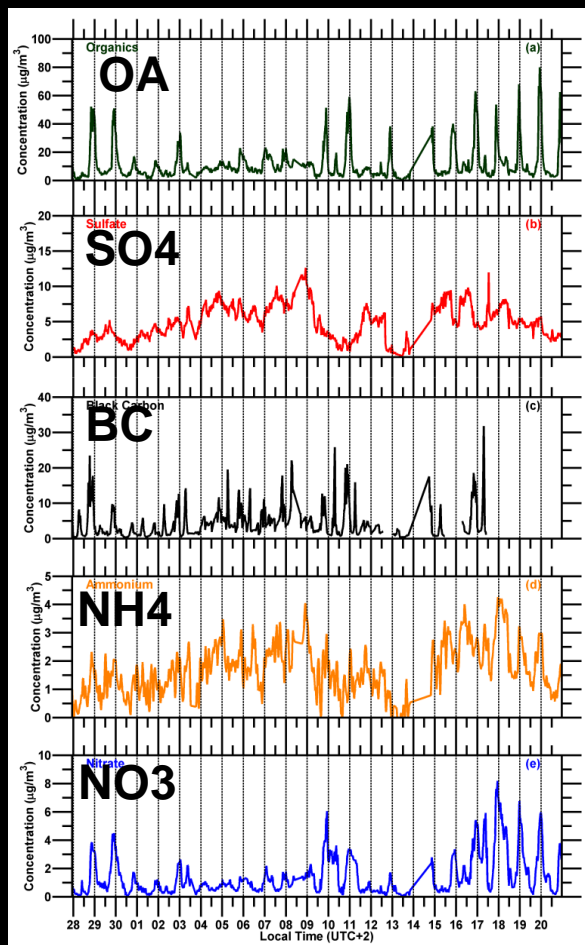


NICOSIA:

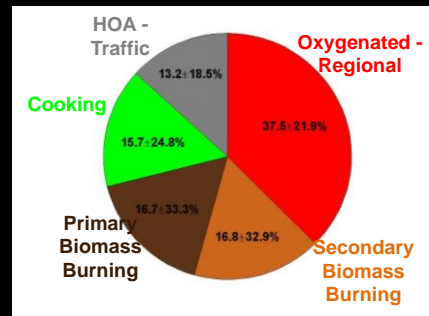
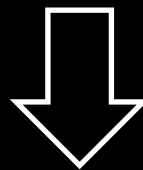
CAO “Urban pollution”



On-line PM₁



Chemical composition PM₁



Source apportionment of OA in PM₁

⇒ Half of PM₁ in Nicosia is produced locally (about 30% in Paris)

⇒ 2/3 of OA is locally emitted (1/3 from regional origin)

⇒ Major influence of biomass burning (domestic heating)

The Cyprus Atmospheric Observatory (CAO)

AGIA MARINA XYLIATOU:











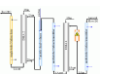






CAO “Cyprus Rural background”



CAO



A large set of state-of-the-art instrumentation

Instrument	Parameter	T	Instrument	Parameter	T
Aerosol chemistry					
Aerosol Chemical speciation Monitor (ACSM) LSCE 	Ions, OM (incl. sources) in PM1	30 min	On-line VOC LSCE+DLI 	VOC (C2-C6)	30 min
Aerosol Chemical Composition DLI+CyI+ECPL 	Ions, EC, OC, PM, metals, in PM ₁ , PM _{2.5} & PM ₁₀	24h	On-line VOC EMD+DLI 	VOC (C6-C12)	30 min
TEOM & TEOM-FDMS DLI+LSCE 	PM _{2.5} & PM ₁₀	6 min	Air quality		
Aerosol physical properties			DLI Ozone Monitor 	Ozone (O ₃)	5 min
LSCE OPC 	N spectra (0.3µm - 20µm)	1 min	DLI Carbon Monoxide Monitor 	(CO)	5 min
LSCE SMPS 	N spectra (0.003µm - 0.8µm)	15 min	DLI Nox Monitor 	NO, NO ₂	5 min
HTDMA TU Delft 	Hygroscopicity	15 min	DLI Sulfur dioxide Monitor 	SO ₂	5 min
Aerosol optical properties					
Aethalometer LSCE 	Absorption PM ₁ (7λ)	5 min	Weather Station + Solar Flux		
Nephelometer LSCE 	Light scattering Coeff. (3λ)	15 min	LSCE + DLI 	P, T, RH, WS, WD, Rad.	5 min
Sunphotometer LOA 	A.O.D (7λ)	15 min	Solar Flux LOA 	(In)direct solar radiation	5 min



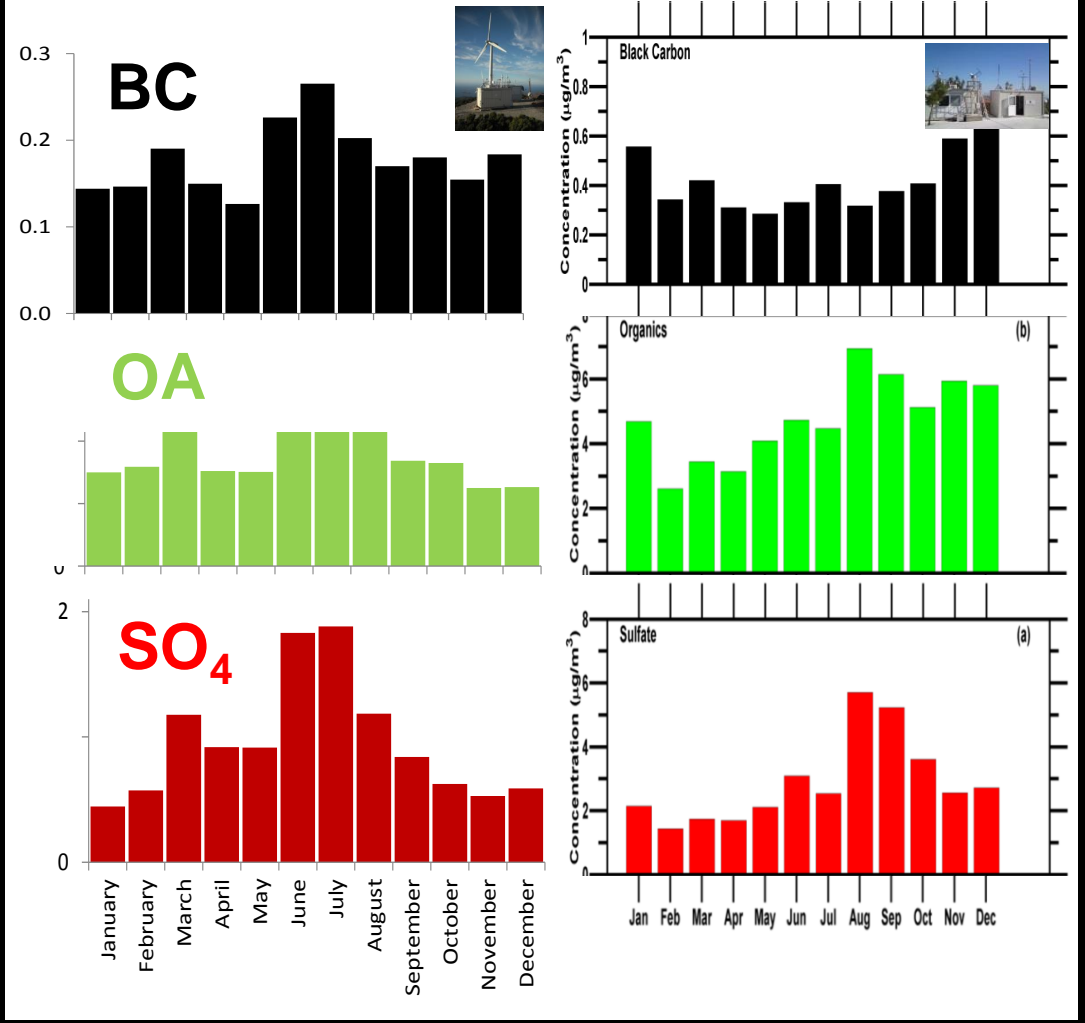
Seasonal variability of PM₁ components:

A major West-to-East gradient in concentrations



Cape Corsica
 Corsica (2012-2014)

Agia Marina Xyliatou
 Cyprus (2015)



⇒ Quite similar seasonal variability with maxima in summer (except for BC)

⇒ Around 3 times BC, OM, SO₄ in E. Mediterranean compared to W. Mediterranean !!!

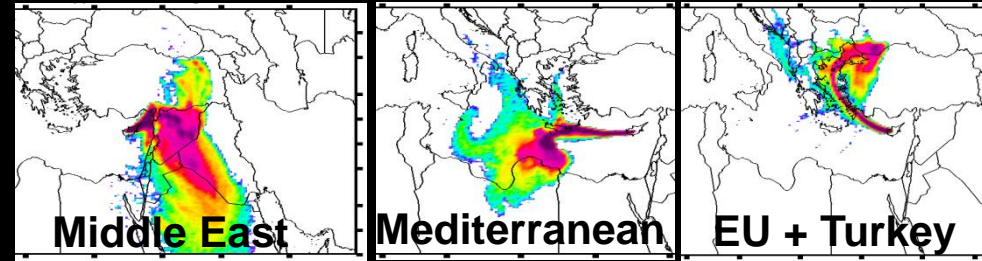


BACCHUS

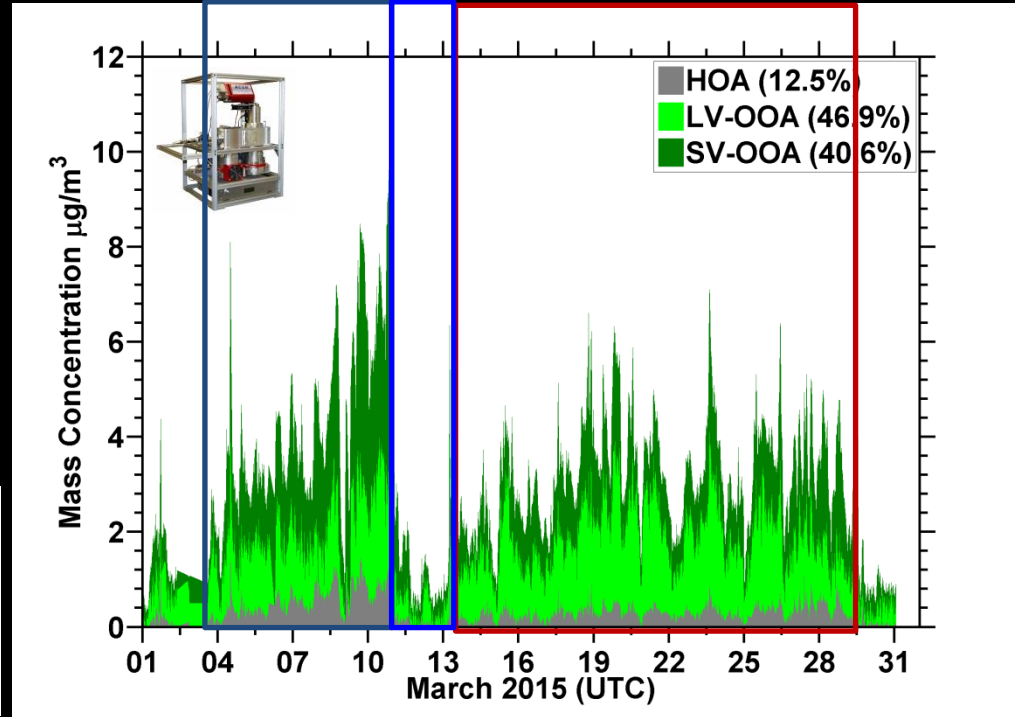
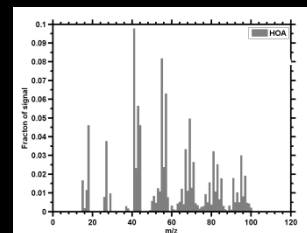
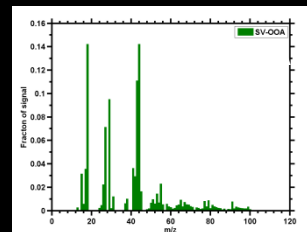
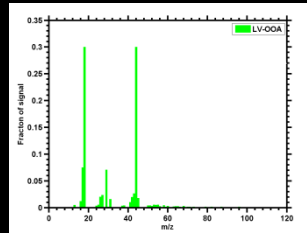
Field Campaign
Cyprus, March 2015

Influence of anthropogenic aerosols

Organic aerosols from the Middle East



Organic Aerosols
Source Profile



Middle East = High levels of primary & semi-volatile Organic Aerosols

Mediterranean = Low levels of highly oxidized Organic Aerosols, NO primary

EU+Turkey = High levels of highly oxidized Organic Aerosols, WITH primary

Unmanned Systems Research Laboratory (USRL)

<http://www.cyi.ac.cy/index.php/usrl.html>



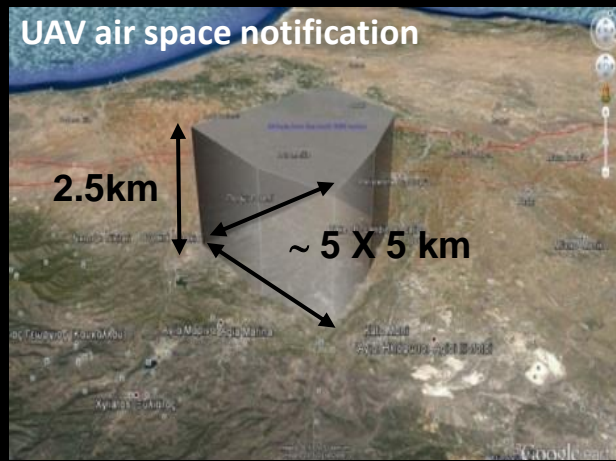
Strategic partners



Mobile Ground Control Station



Aerial view of the Cyl runway (Feb. 2016)



Private UAV flight zone at Agia Marina Xyliatou

Unmanned Systems Research Laboratory (USRL)

Fleet of Unmanned Aerial Vehicles (UAVs)

Fixed wing



4 UAVs

Cruiser
Medium Size: 35 Kg
Payload: 12 Kg
Endurance: 4 hours
Ceiling: 4 Km



1 UAV

Mini Cruiser
Small Size: 11 Kg
Payload: 4.5 Kg
Endurance: 3 hours
Ceiling: 4 Km



2 UAVs

Skywalker EVE
Small Size: 5.5 Kg
Payload: 2.5 Kg
Endurance: 2hours
Ceiling: 3 Km



3 UAVs

Skywalker 1680
Small Size: 4 Kg
Payload: 1.5 Kg
Endurance: 1.5 hours
Ceiling: 3 Km

Rotary Wing



1 UAV

Logo 800
Small Size: 12 Kg
Payload: 5 Kg
Endurance: ~30 minutes
Ceiling: 3 Km



1 UAV

Dji S1000+
Small Size: 11Kg
Payload: 4 Kg
Endurance: ~20 minutes
Ceiling: 1 Km

Unmanned Systems Research Laboratory (USRL)

Integration of new miniaturized instrumentation

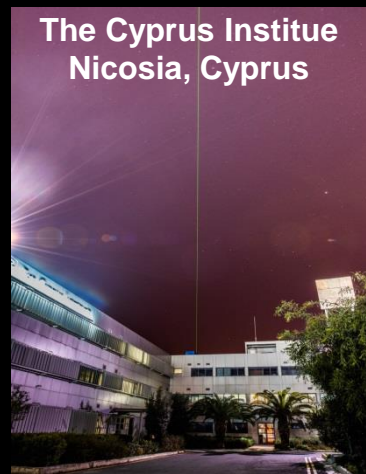
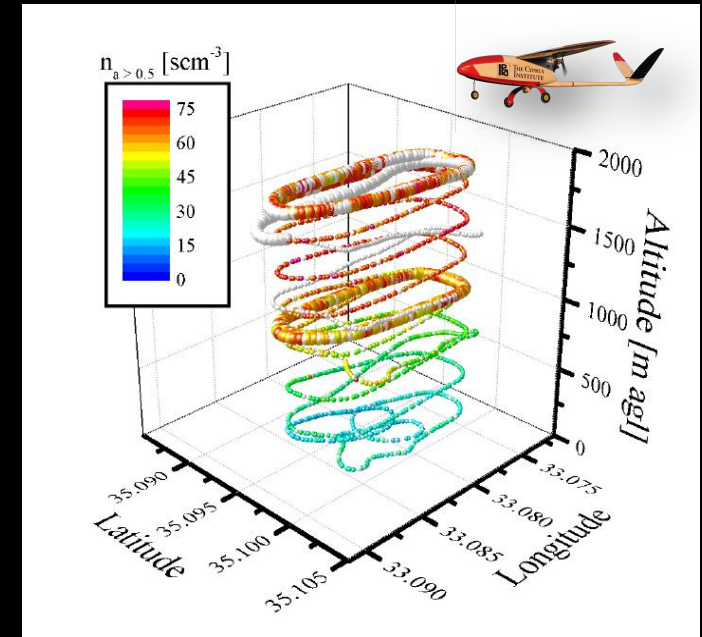
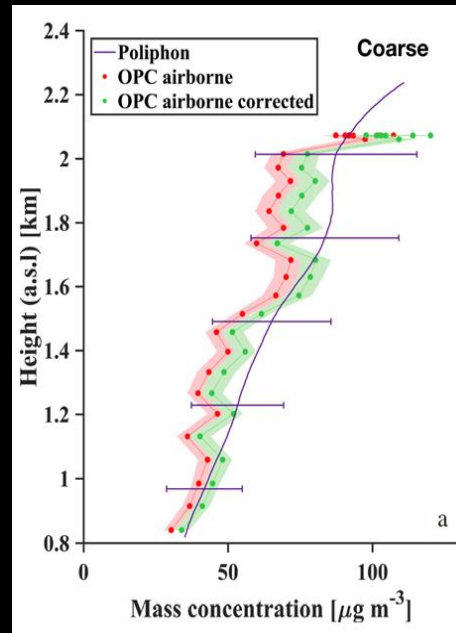


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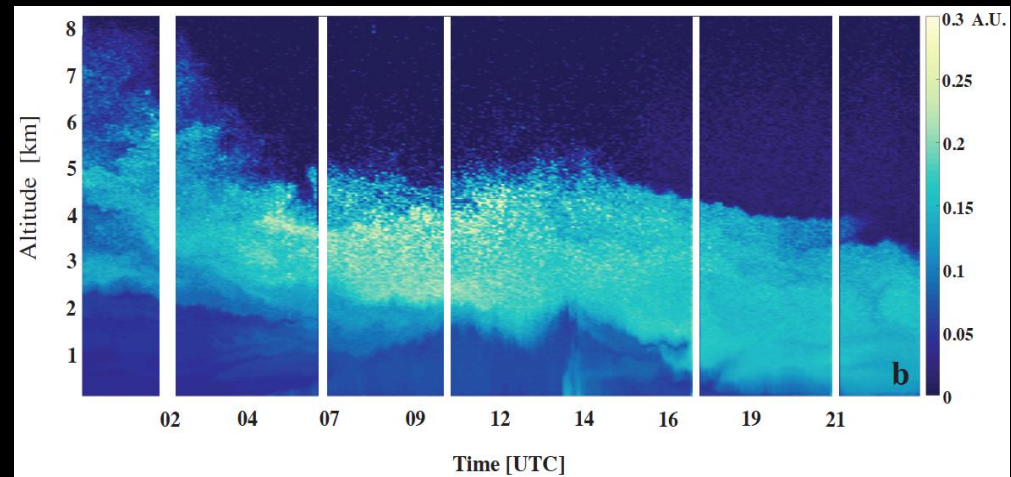
Field Campaign
Cyprus, April 2016

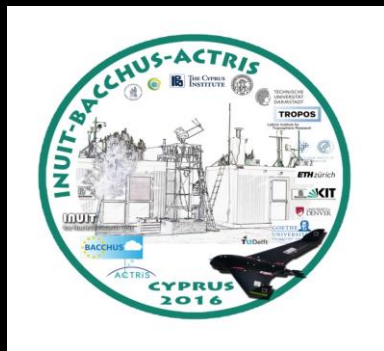
Contribution of UAV observations

Calibration of remote sensing observations



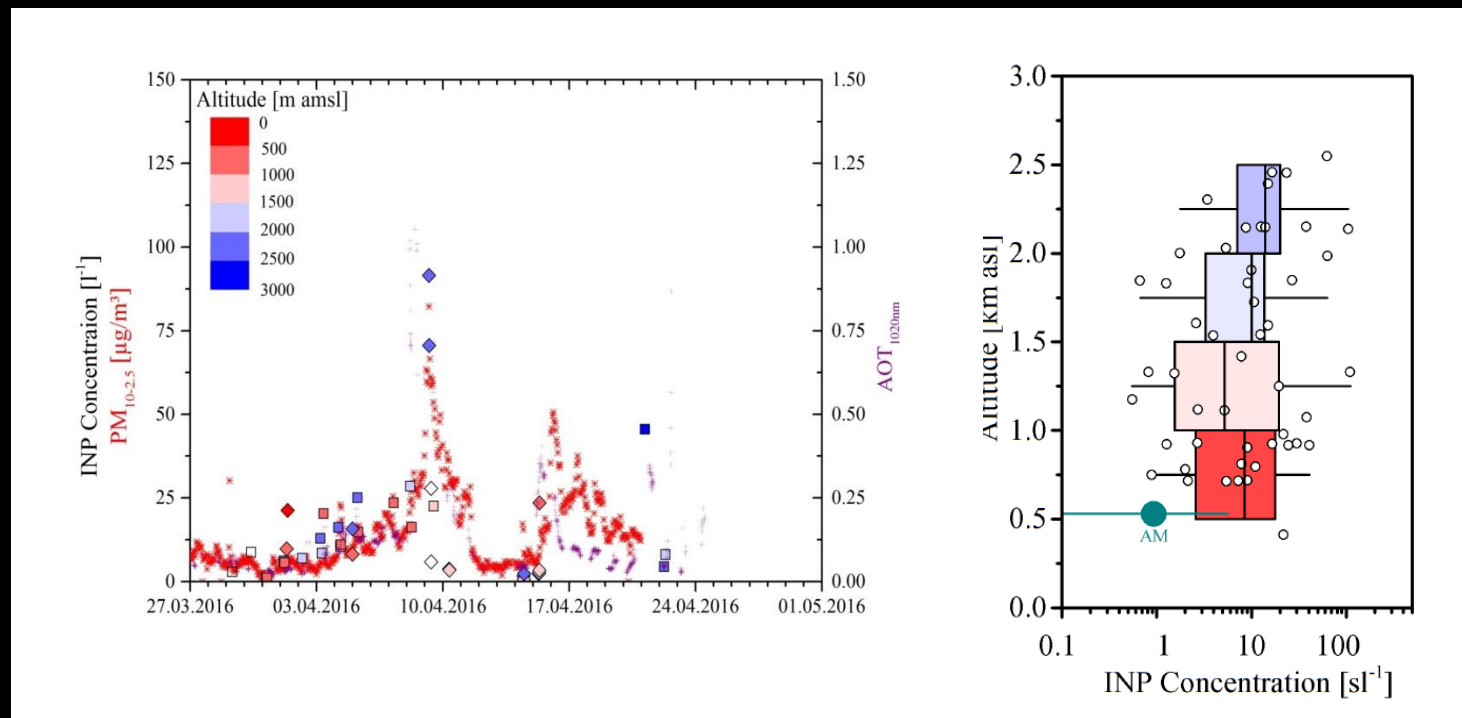
The Cyprus Institute
Nicosia, Cyprus





$[INP] = f(\text{altitude, time})$

INP concentrations
($T = -30\text{C}$, $RHI = 135.4\%$, circles)



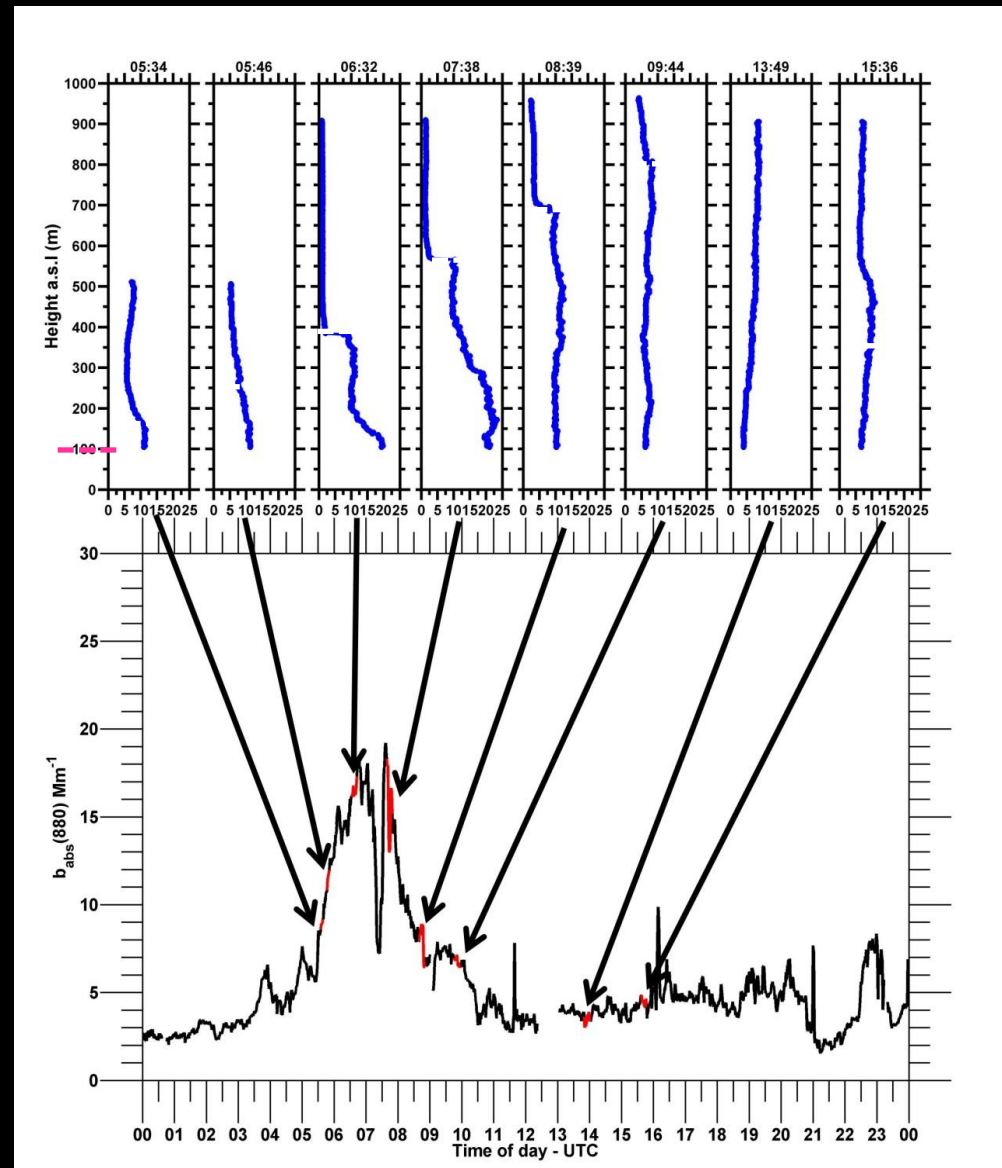
ACTRIS

Field Campaign
Athens, January 2016
EU-H2020-ACTRIS2
(January 2016)



Platform: Octocopter (MTOW 11Kg)
Total of 26 vertical profiles
10-15 minutes for each vertical profile!
Intensive Day Measurements
(1 vertical profile every 1 hour from dawn to dusk)

Contribution of UAV observations vertical profiles of Black Carbon (0- 1km)



Pikridas et al., Atmos. Meas. Tech., submitted, 2017

Conclusions

Our first in-situ continuous Atmospheric monitoring have shown that



- ✓ the Eastern Mediterranean Middle East (EMME) region shows **high levels of PM pollution** (3 times higher compared to W. Med) with **major influence of Middle East air pollution**
- ✓ **Half of PM pollution in Nicosia is produced locally**; domestic (**wood burning**) heating being a major pollution source during winter

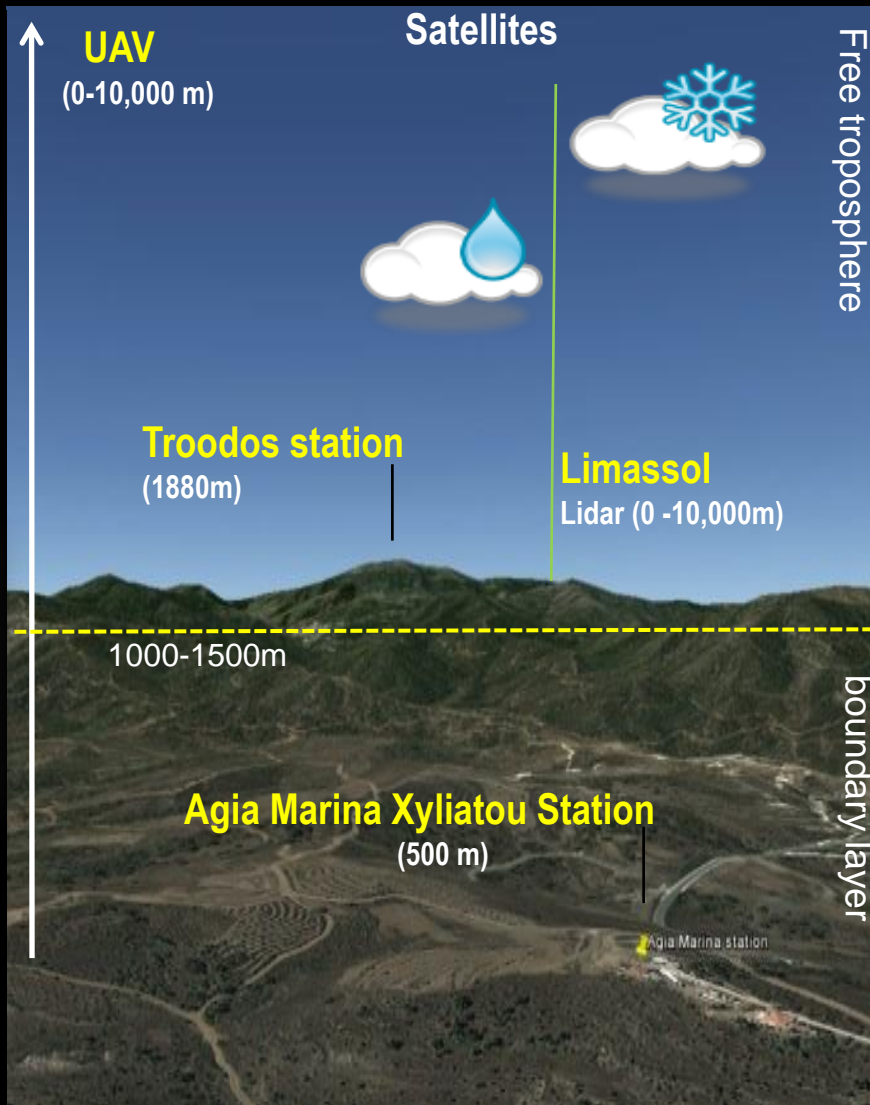
Our first UAV-based atmospheric observations have shown



- ✓ The influence of vertical mixing in the boundary layer on the ground-based urban (traffic) pollution
- ✓ The need to perform in-situ aerosol (Ice Nuclei, PM) measurements in the atmospheric column to further **constrain/calibrate remote sensing observations.**

Perspectives & Potential collaborations with CUT

Long-term atmospheric observations over Cyprus



Satellites



Limassol – Lidar LACROS

UAVs



Troodos



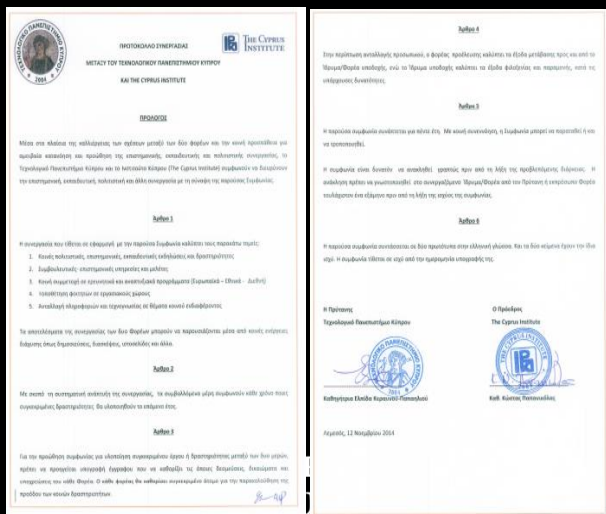
Agia Marina Xyliatou Station

Perspectives & Potential collaborations with CUT

Research projects

No	Project title	Acronym	Funding agency	Call	Cyl Center	PI	Role	Start date
1	Impact of biogenic versus anthropogenic emissions on clouds and climate: towards a holistic understanding	BACCHUS	EC - FP7	FP7-ENVIRONMENT	EEWRC	N. Mihalopoulos	Partner	Running
2	Aerosols, Clouds, and Trace gases Research InfraStructure	ACTRIS 2	H2020	H2020-INFRAIA-2014-2015	EEWRC	Jean Sciare	Partner	Running

Collaboration framework



- Memorandum of Understanding (Nov. 2014)
- CUT – Cyl affiliation of R. Mamouri

Perspectives & Potential collaborations with CUT

Water Resources

- Climate change adaptation in agriculture
- Improving mountain agriculture
- Water-energy projections, economics and policies

Atmosphere & Climate

- Air pollution monitoring (ACTRIS) – Synergy between remote sensing (CUT) versus in-situ (Cyl) [potential of UAVs] – *RPF / ESA proposal*
- Competitive International summer/winter schools with hands-on training in the field
- **PhD research opportunities for CUT MSc graduates (Energy, Environment, Water)**

Thank you for your attention

