

# **MEDITERRANEAN AND MIDDLE EAST AIR POLLUTION IN A CHANGING CLIMATE**

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## ***Thanks to:***

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***J. Sciare (Cyl, Cyprus),***

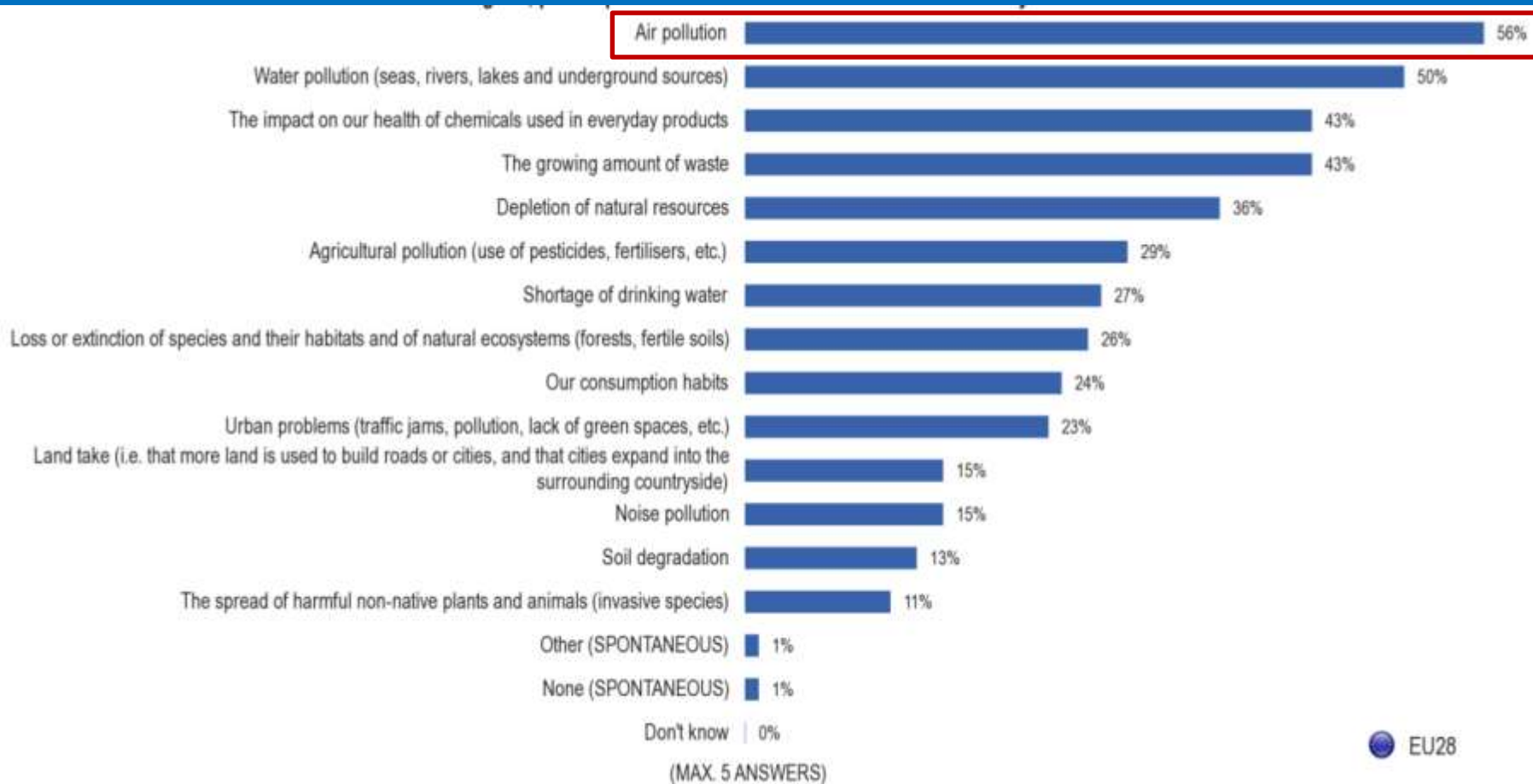
***M. Vrekoussis (Bremen & Cyl)***

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- ***Drs P. Ciais (France)***

- ***Drs. G. Kouvarakis, K. Bougiatioti ,  
C. Theodosi, D. Paraskevopoulou***

# Air pollution : First environmental concern of EU citizens



*Source: Special Eurobarometer 416 (2014)  
Attitudes of European citizens towards the environment*

Los Angeles



Athens



Beijing



Sao Paulo



Singapore



Mexico City

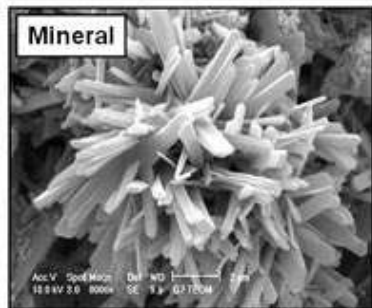
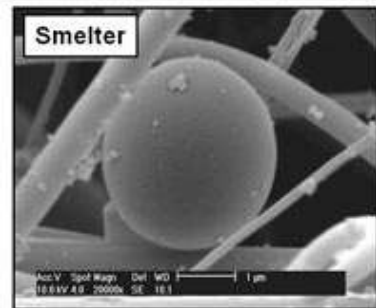
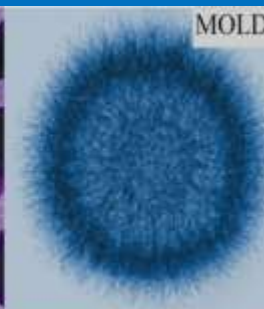
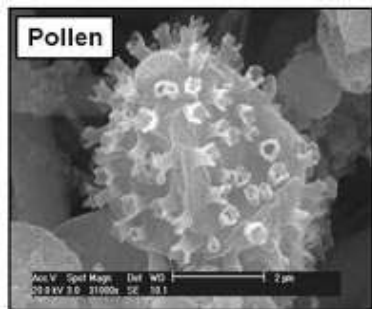


# Air pollution : What are we talking about ?

*Anthropogenic*

*versus*

*Natural*



*Sources ?*

# PM<sub>10</sub>

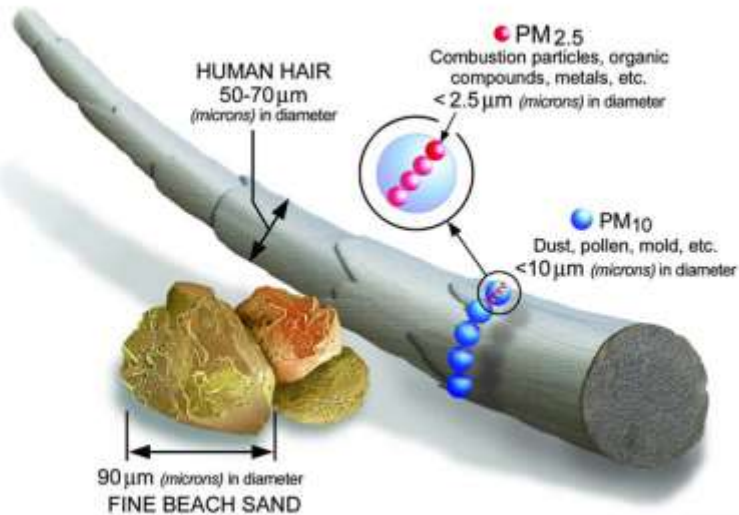
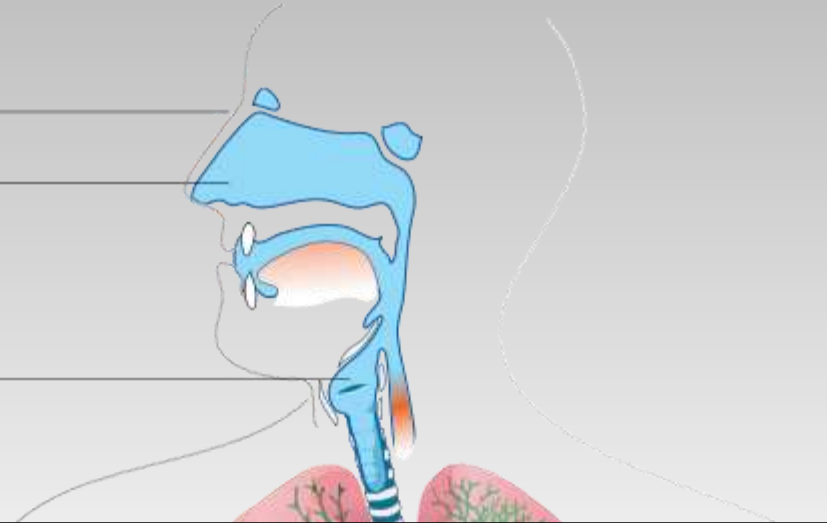


Image courtesy of the U.S. EPA

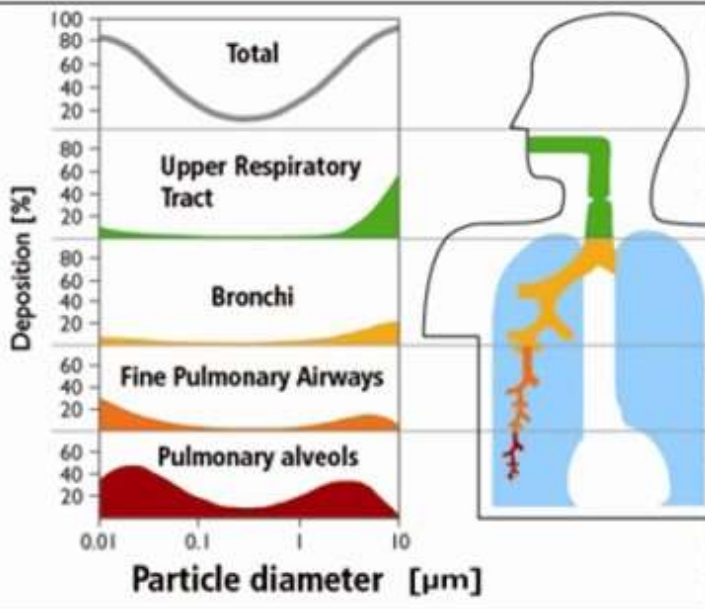
9,0 - 10,0 μm

Naso  
5,8 - 9,0 μm

Laringe  
4,7 - 5,8 μm



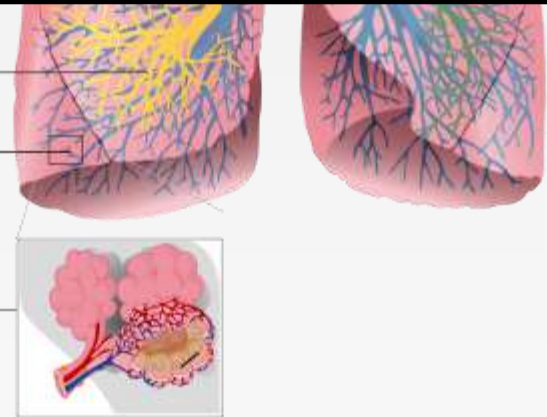
✓ The surface area of human lungs in contact with ambient air is equivalent to the superfcy of a tennis court



Bronchi secondari  
2,1 - 3,3 μm

Bronchi terminali  
1,1 - 2,1 μm

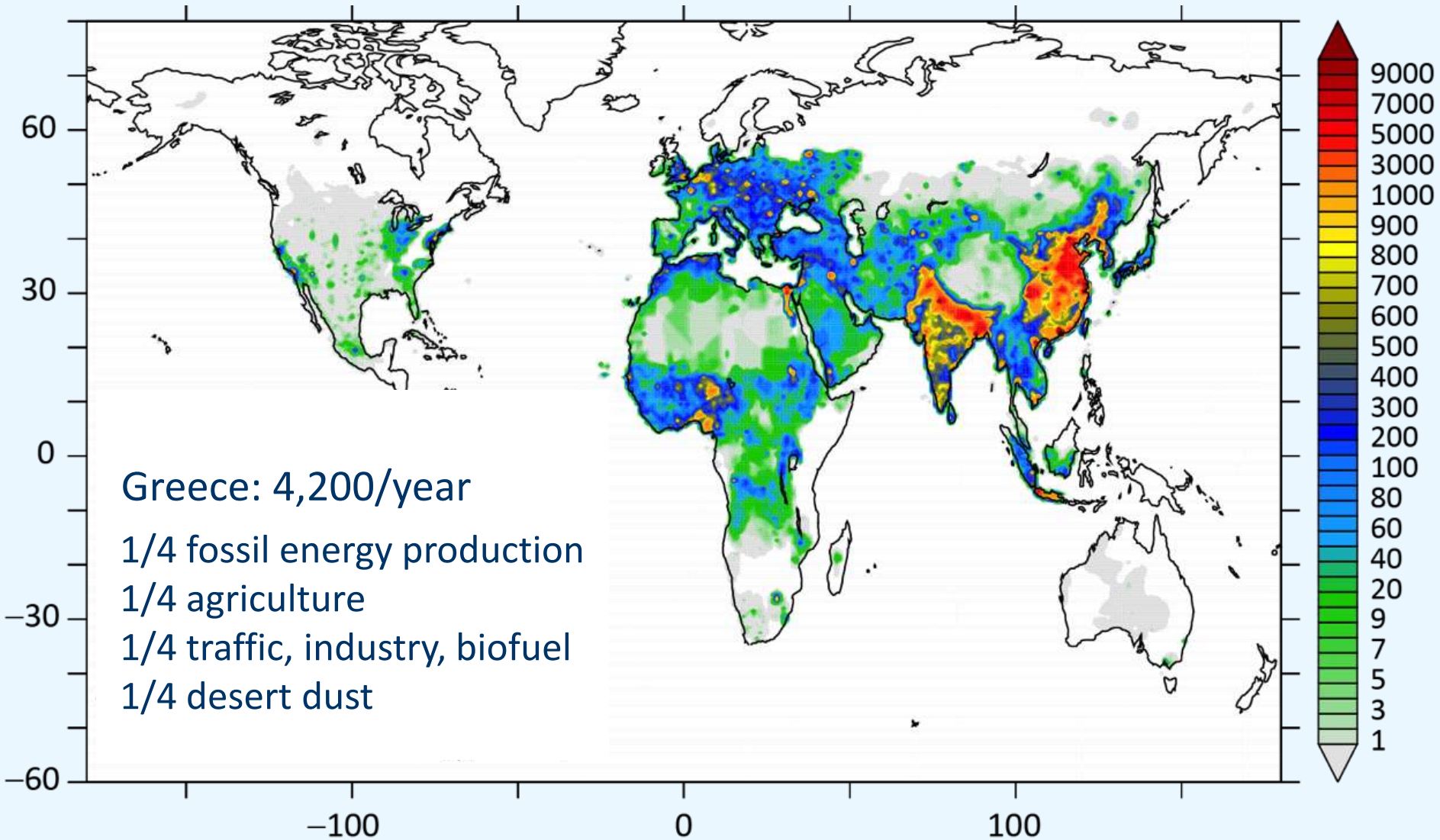
Alveoli  
0,65 - 1,1 μm  
0,43 - 0,65 μm



✓ The smallest particles (< 100nm) go deep in the human bronchial (alveoles)

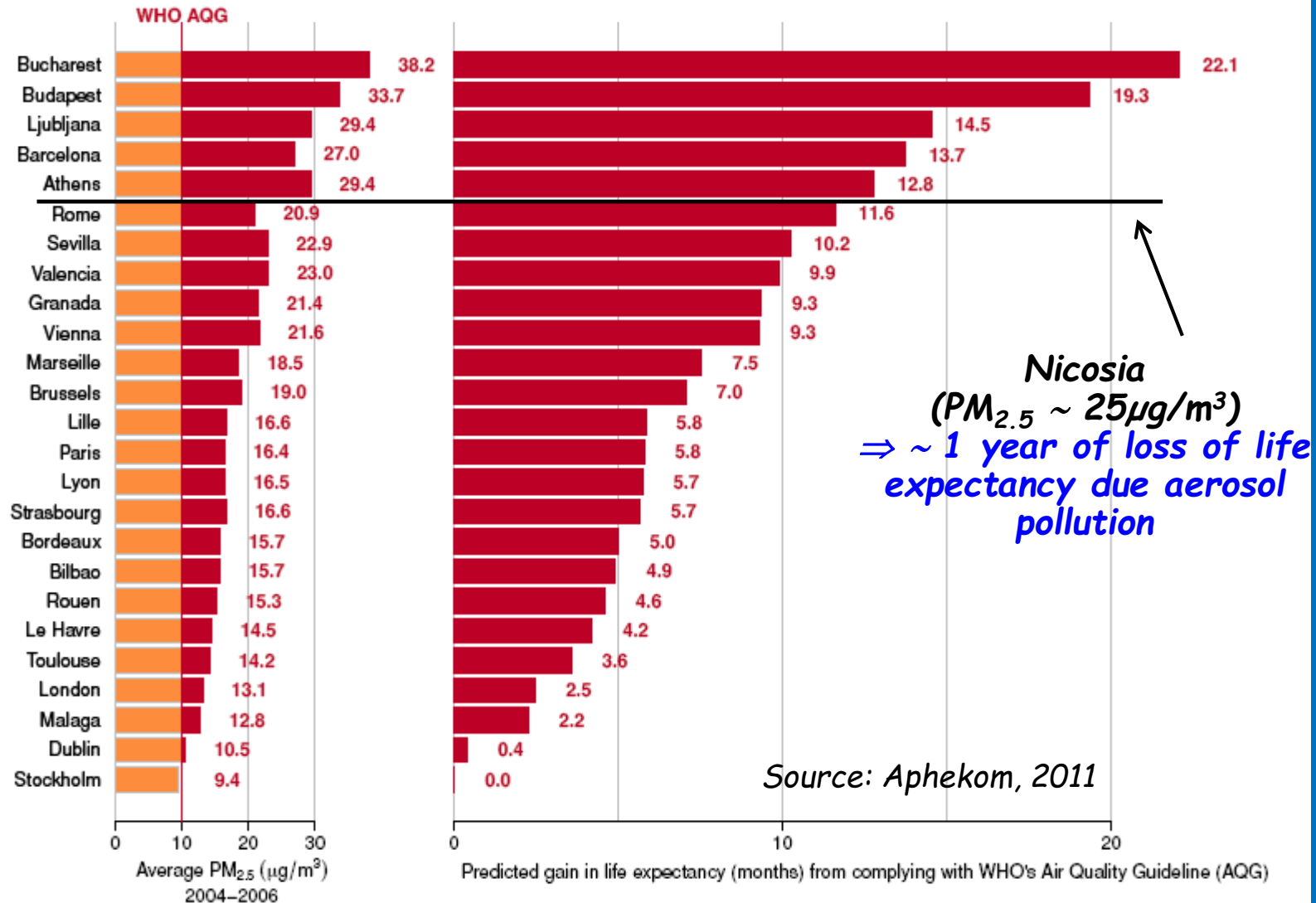
# Annual premature mortality attributable to air pollution

Individuals per  $100 \times 100 \text{ km}^2$  – Globally 3.3 million/year



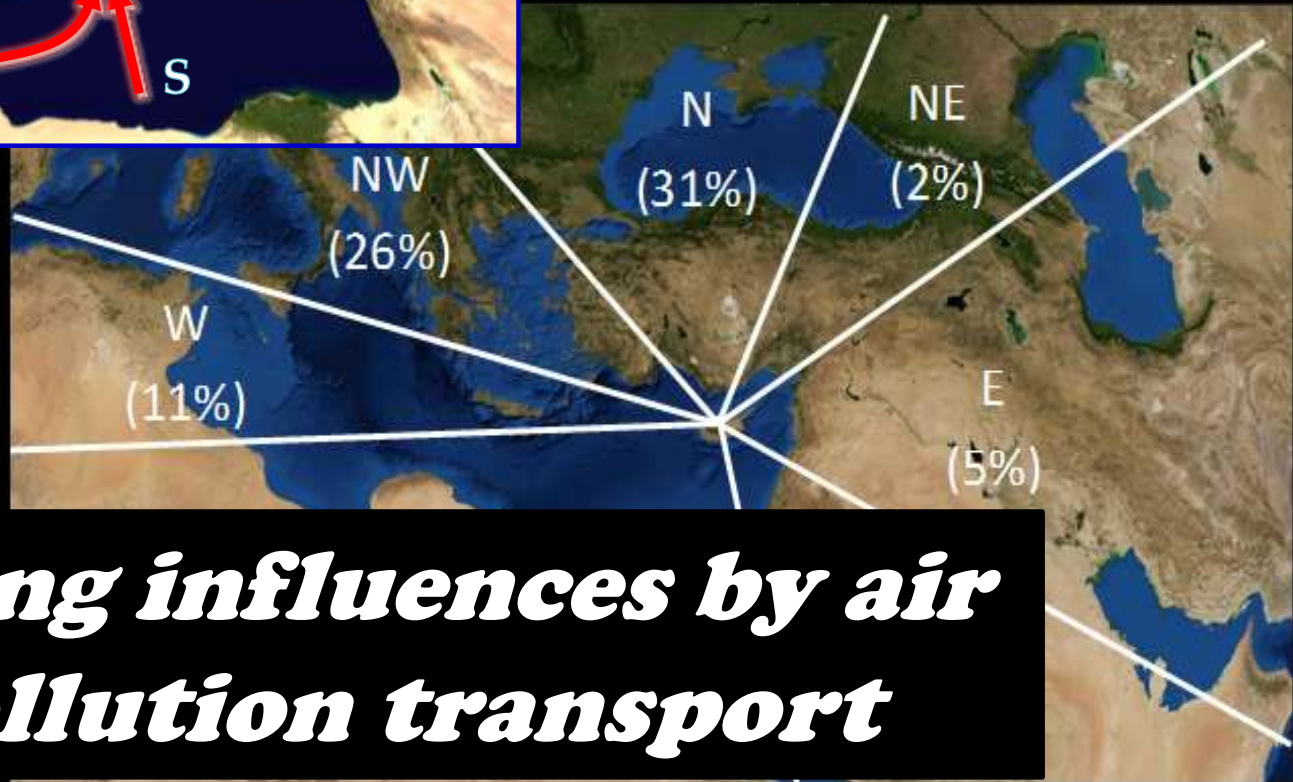
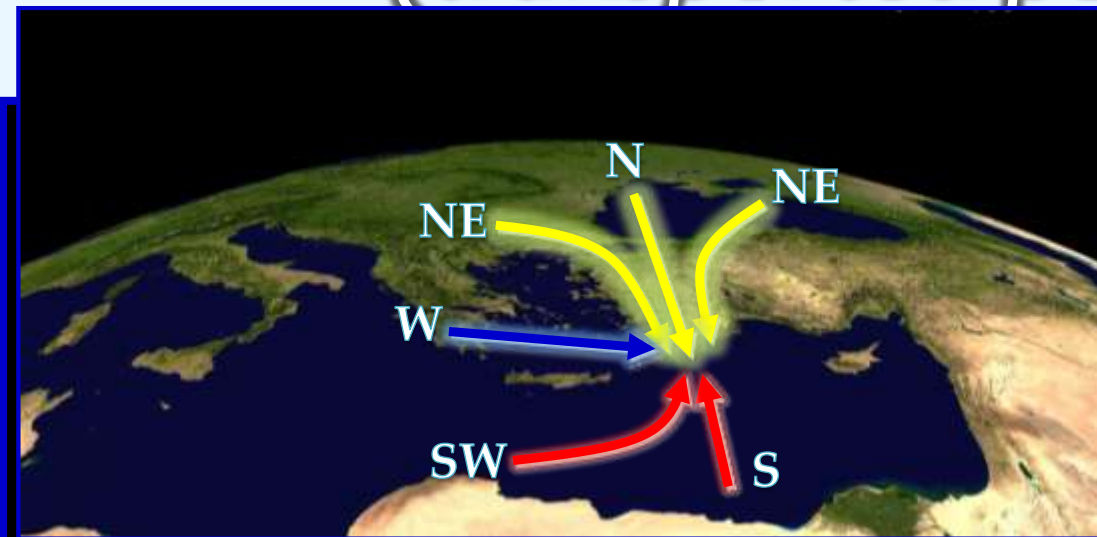
# Aerosols : Health impact (2/2)

Predicted average gain in life expectancy (months) for persons 30 years of age and older in 25 Aphekom cities for a decrease in average annual level of PM<sub>2.5</sub> to 10 µg/m<sup>3</sup> (WHO's Air Quality Guideline)

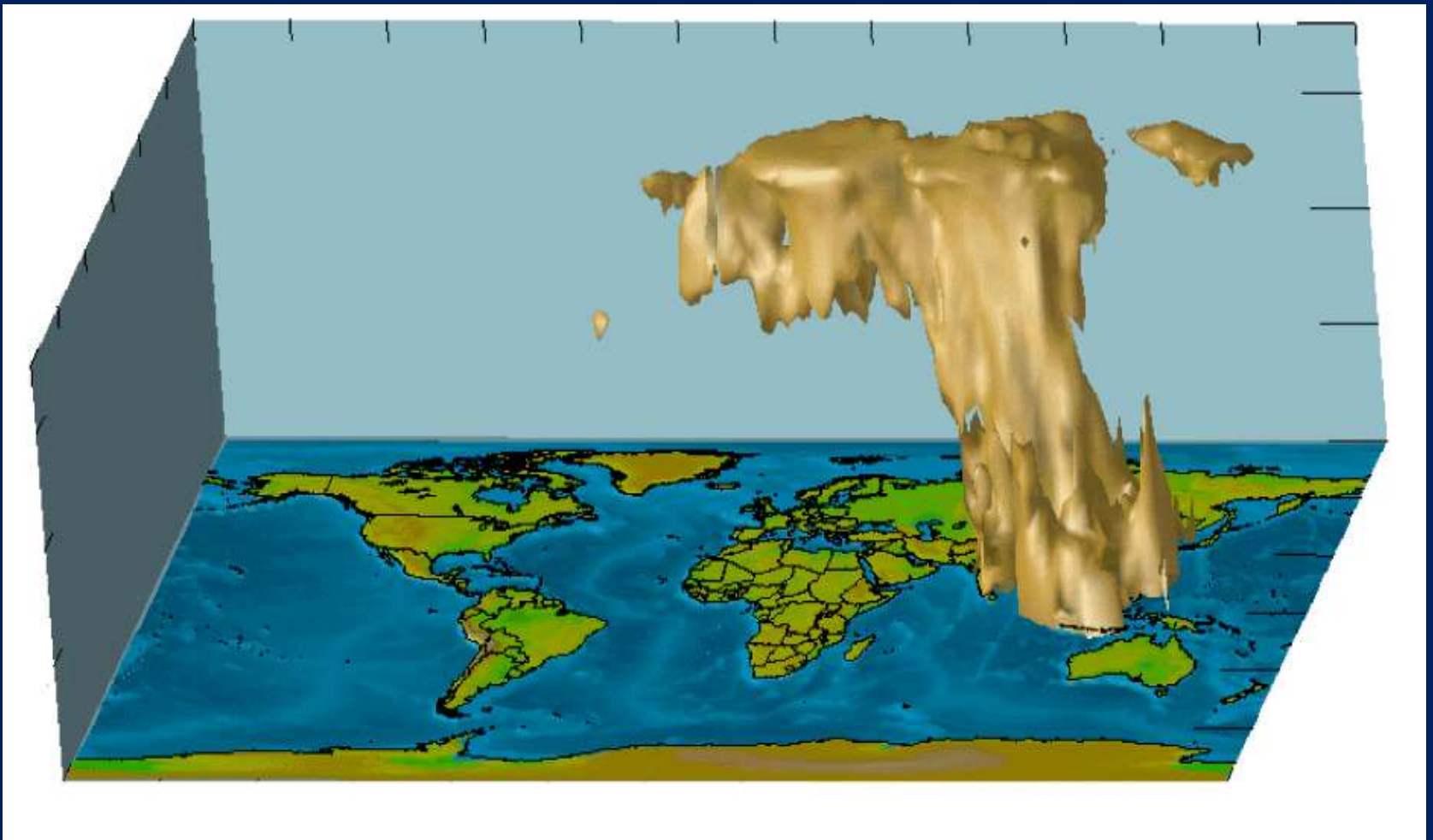




# Why the Mediterranean region? (transported pollution)



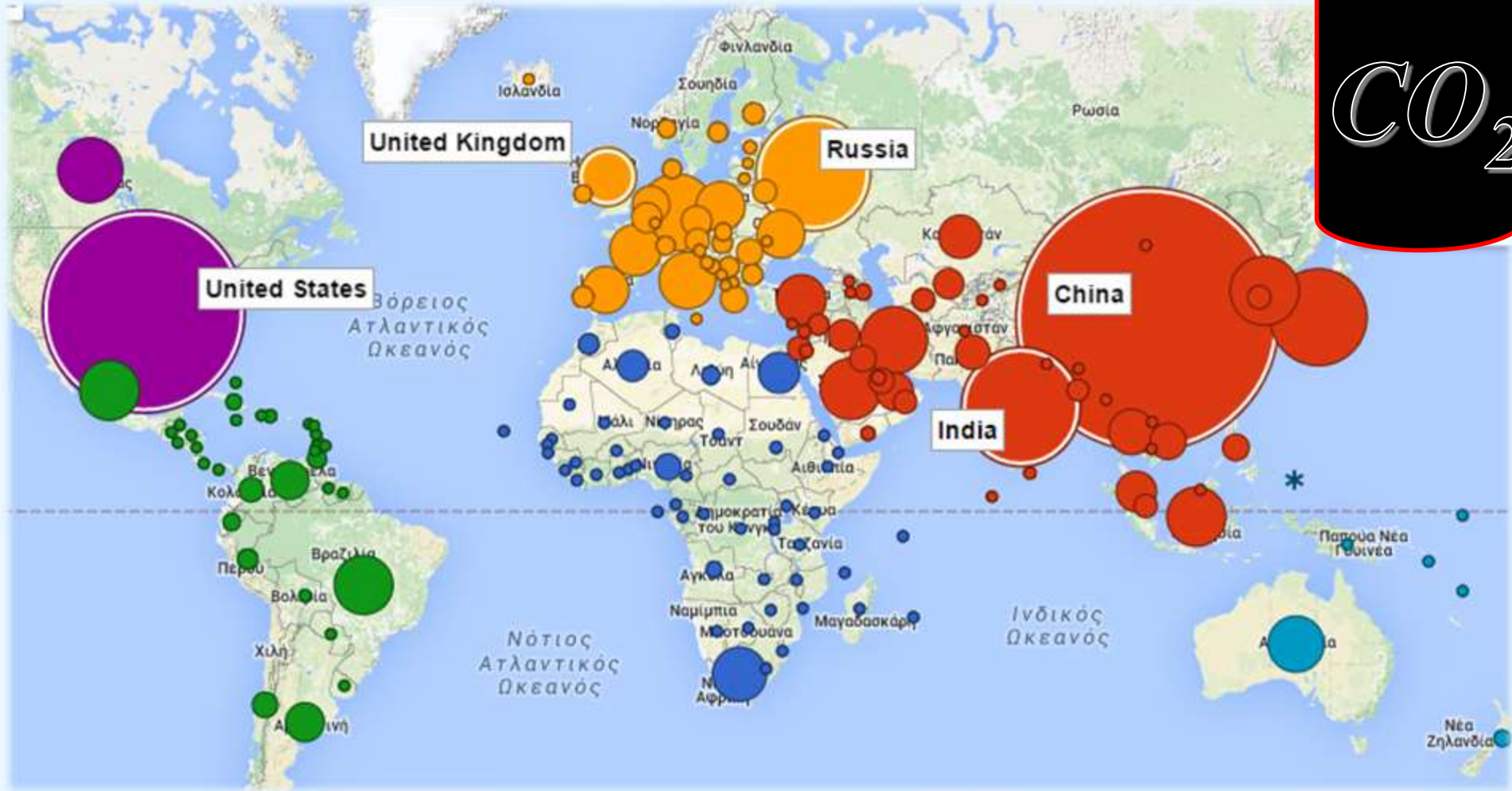
***Strong influences by air  
pollution transport***



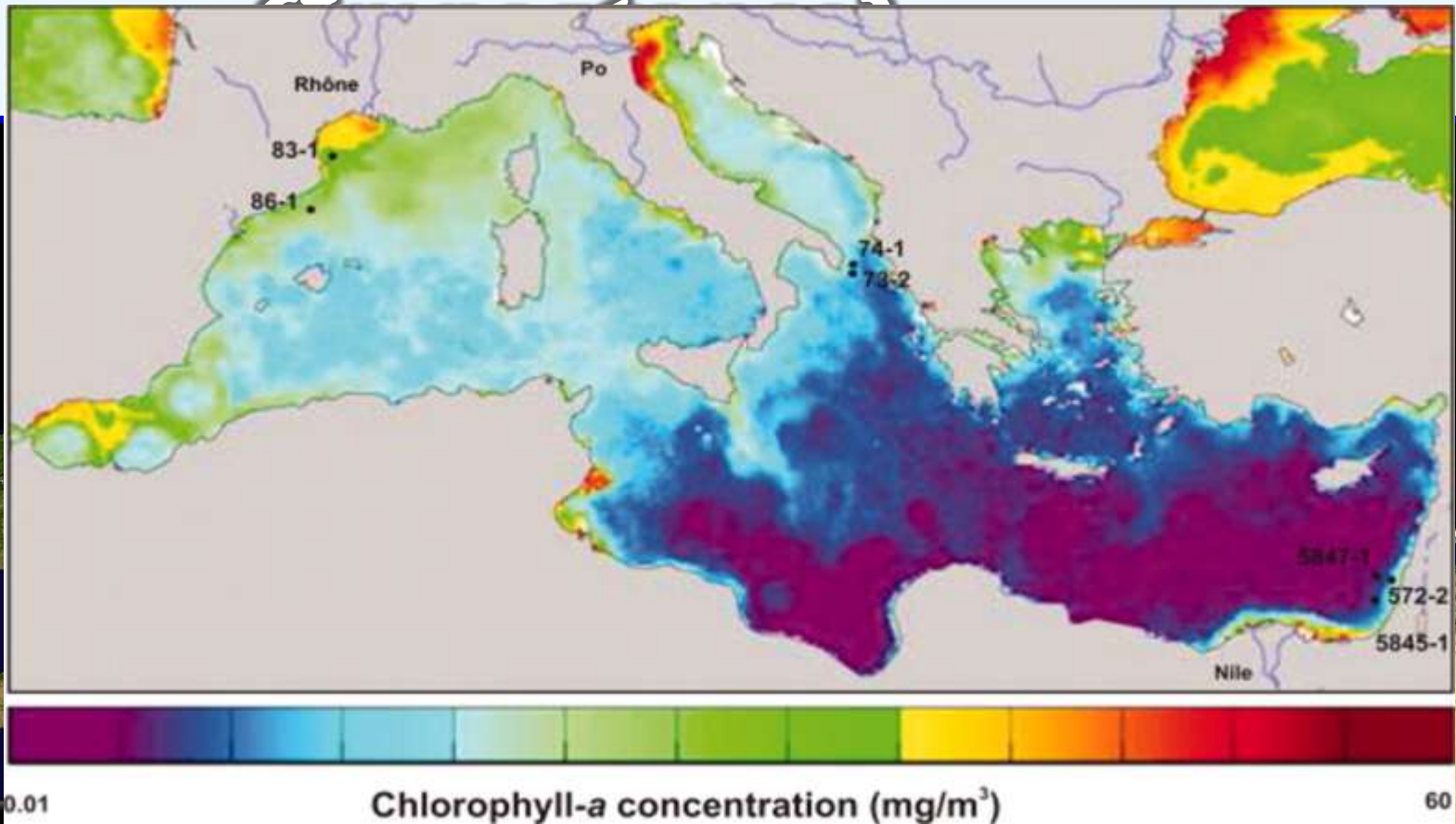
*Model calculation of pollution transport from South Asia (Lawrence et al., 2002).*

*Thunderstorms in the summer monsoon carry pollution to the Mediterranean at altitudes above 8-10 km (the upper troposphere).*

CO<sub>2</sub>

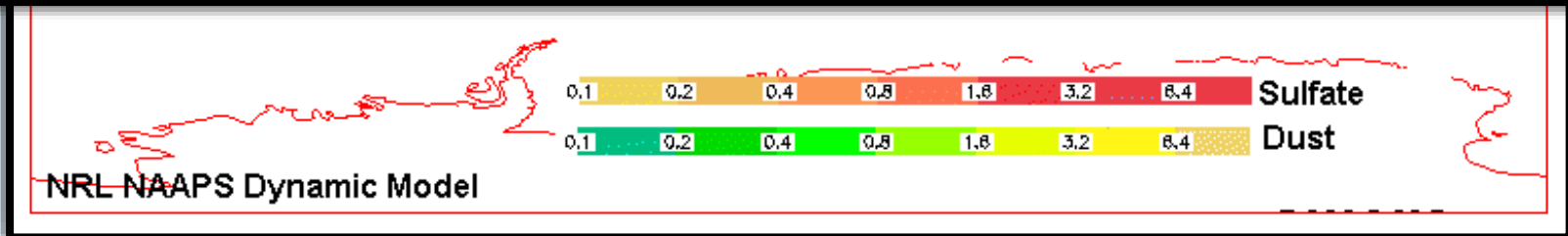
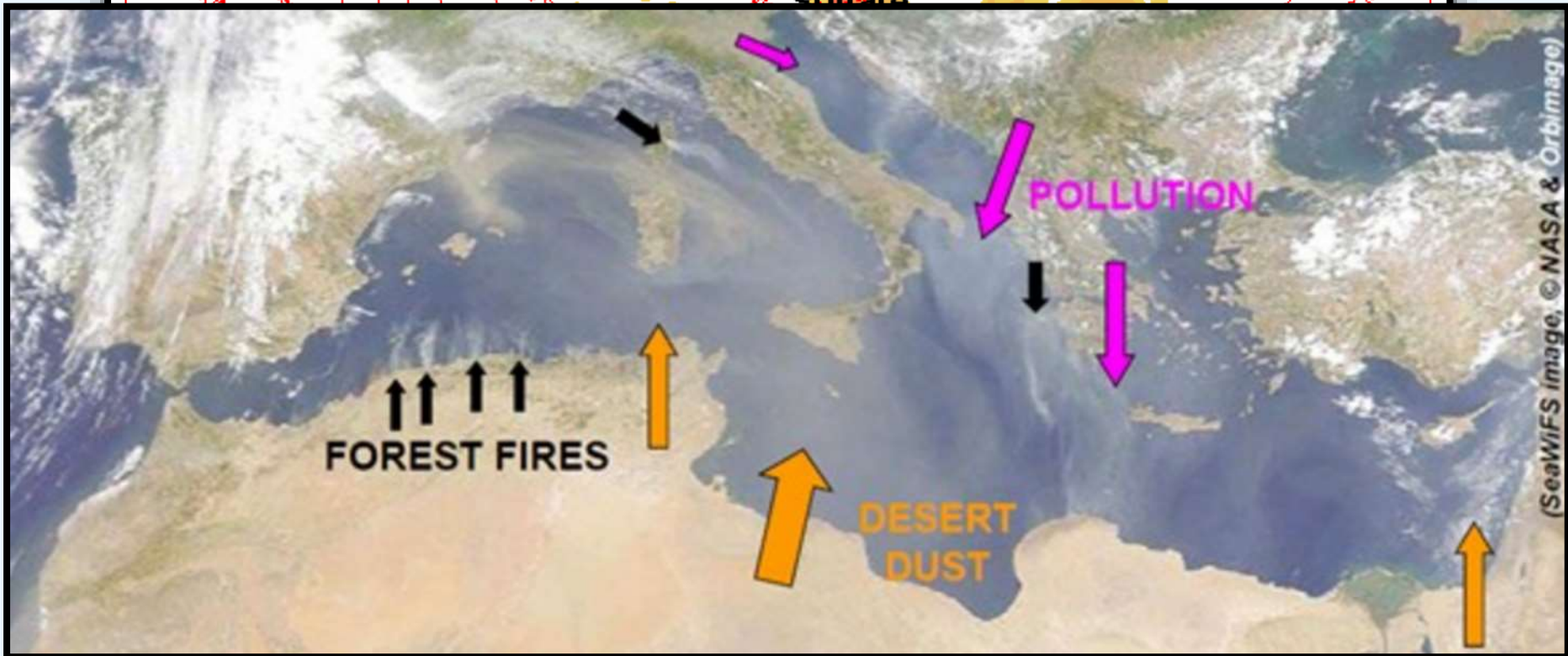
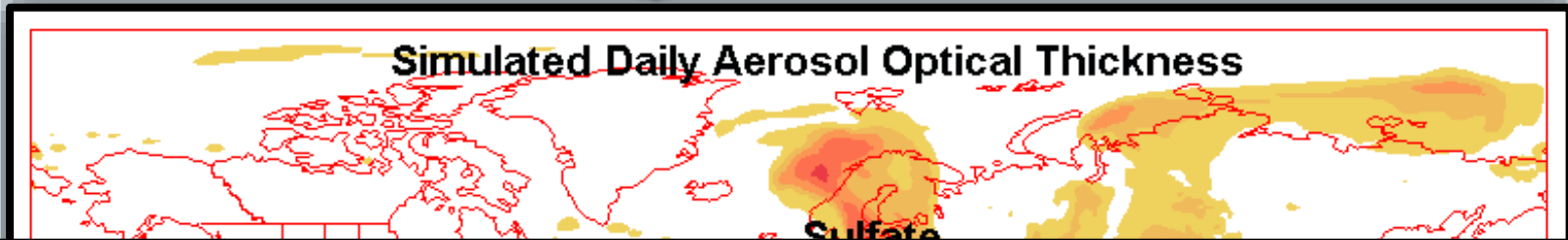


# ***Why the Mediterranean region?***



***Small-scale coupled  
ocean-atmosphere  
system***

# Mixture of pollution sources



# ***Why the Mediterranean region?***

## ***Frequent dust events***



# ***Why the Mediterranean region? (biomass burning)***

*Seasonal variation  
of biomass burning  
sources around E.  
Mediterranean*



**Jul.-Sep.**

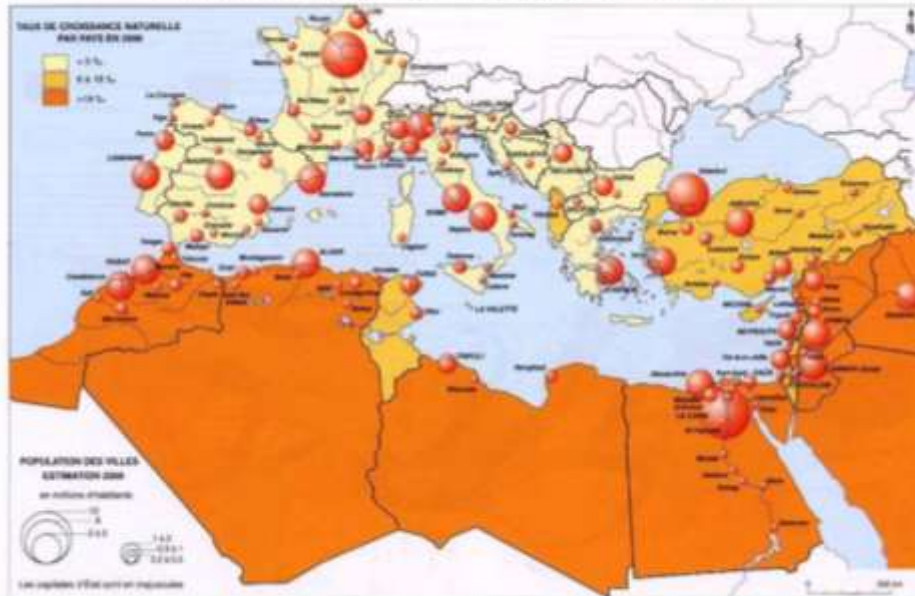


**Oct.-Dec.**

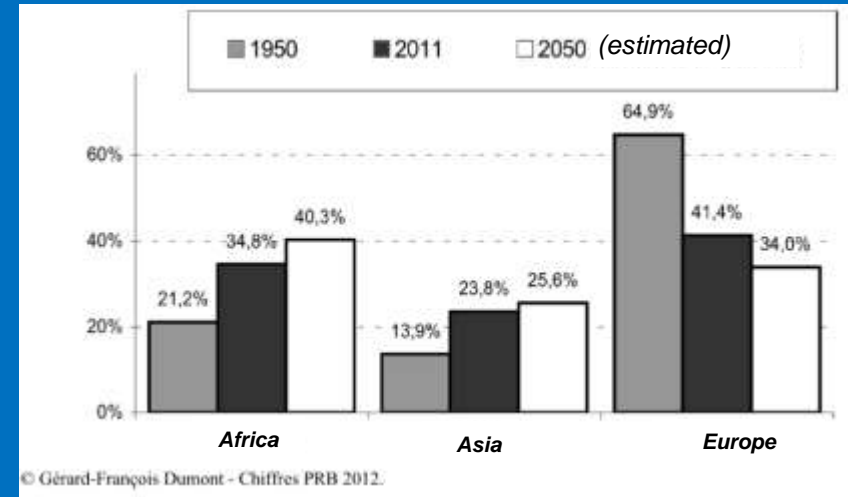


# *Human exposure to air pollution in the Mediterranean*

*Population around the Mediterranean (2000)*



*Fraction of population per continent in the Mediterranean*



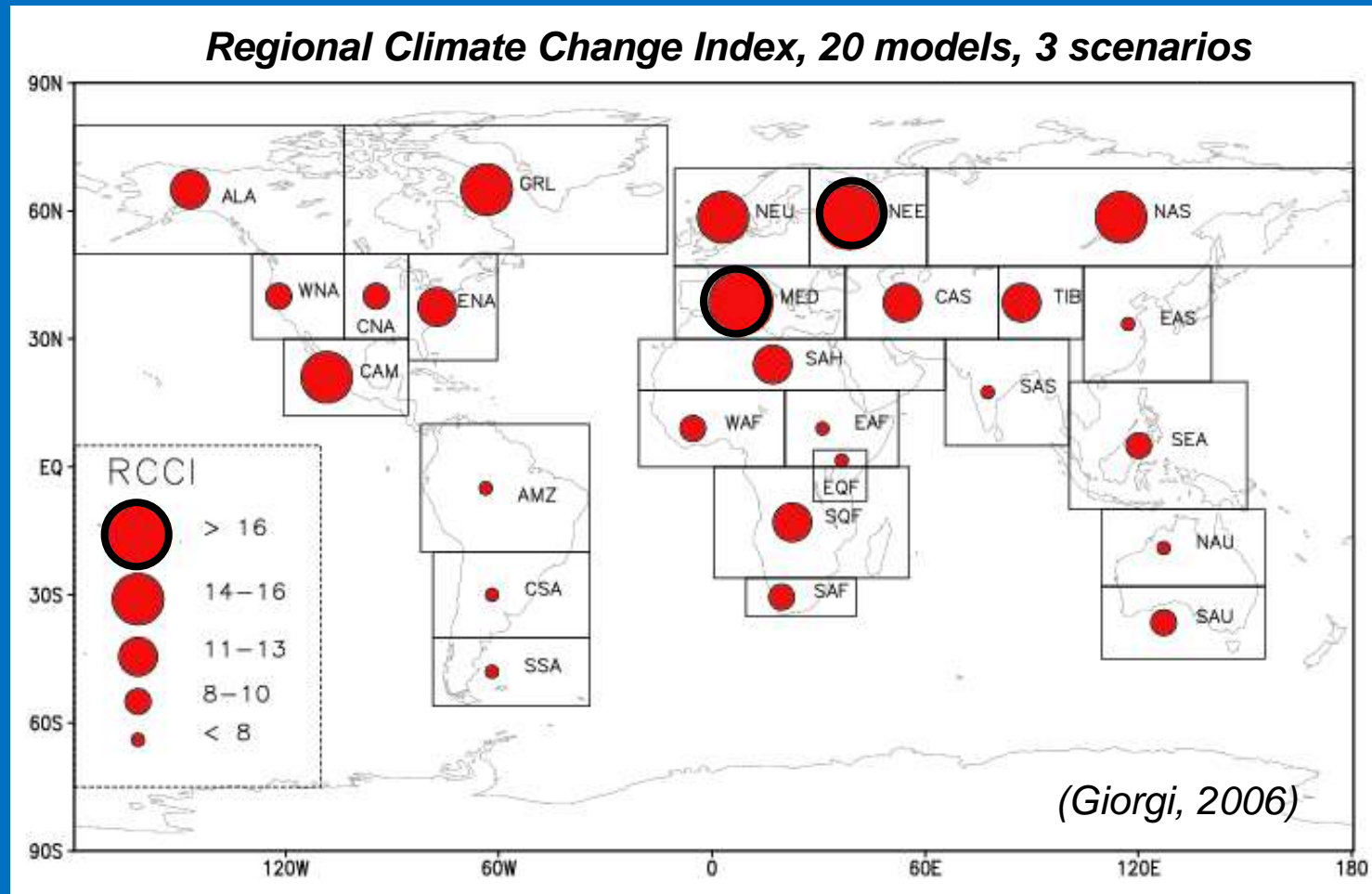
- ✓ *A high anthropogenic pressure around the Mediterranean with almost half a billion of inhabitants*
- ✓ *A strong increase of the population in the Southern and Eastern Basin with more than half of the Mediterranean population leaving out of Europe (N. Africa and Middle-East)*



# Air pollution & Climate Change in the Mediterranean

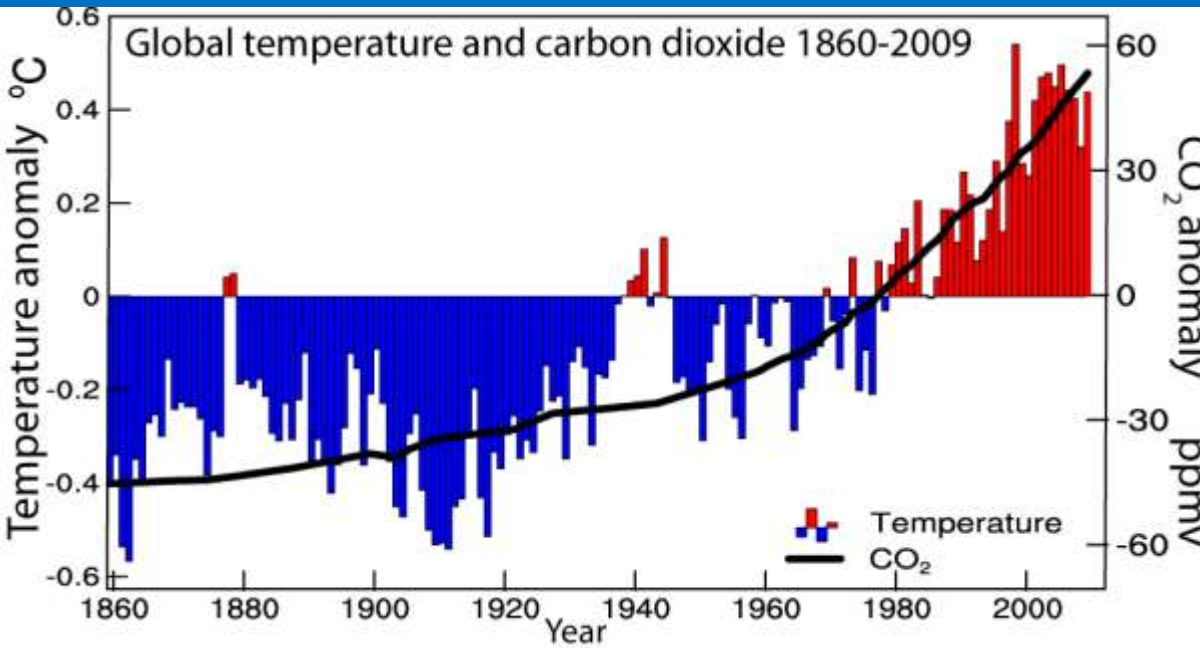
## The Mediterranean: A major climate Hot Spot region

- The Mediterranean is one of the two main Hot Spot regions of the climate change



➤ Climate is responsive to global change in Mediterranean

# Climate Change & Air pollution in the Mediterranean



*Global temperature and its relationship with carbon dioxide for the years 1860-2009. - Updated from Karl and Trenberth, 2003.*

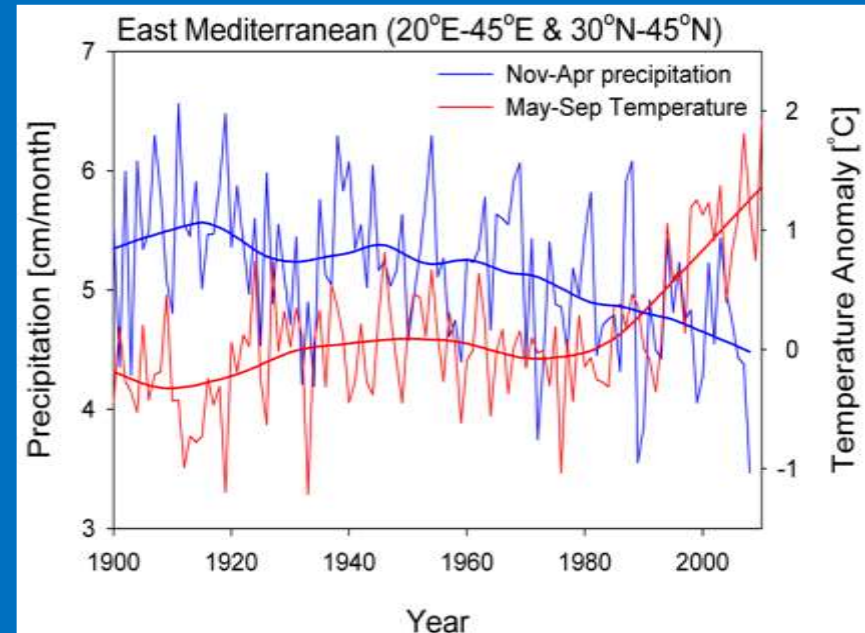
*(Baseline period: 1961-1990)  
Source: <http://www2.cgd.ucar.edu/>*

## Climate Change between 1980-2010

*World : = +0.5 degree C*

*Eastern Mediterranean = +1.5 degree C !!!*

*High Impact region: trends in temperature and precipitation go in different directions  
(The World Bank, 2012)*



# *Regional climate models at the Cyprus Institute*

## *Coupled Model Inter-comparison Project Phase 5 – CMIP5:*



Temperature projections

⇒ ***Summer will become warmer***

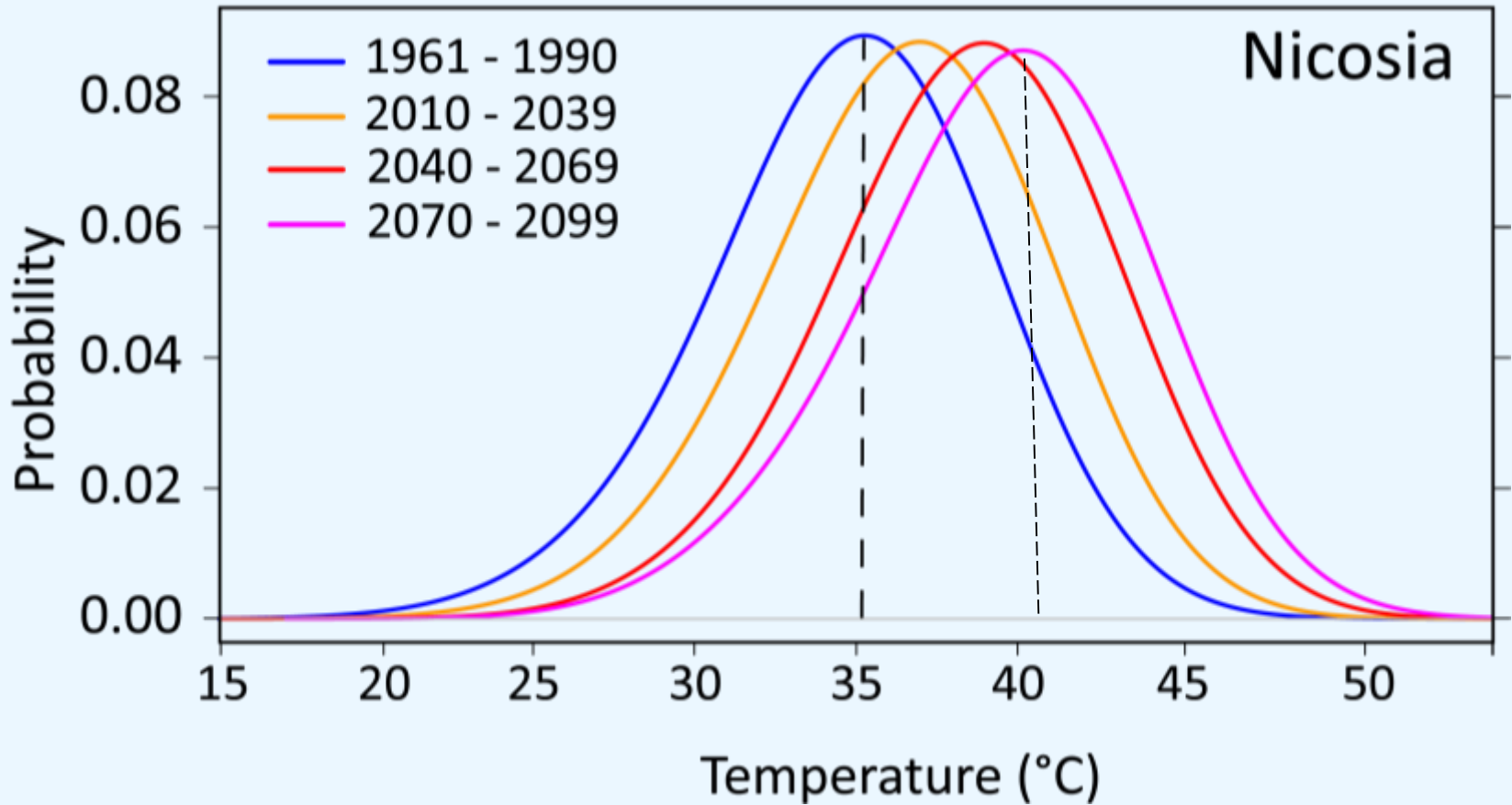


Precipitation projections

⇒ ***Winter will become dryer***



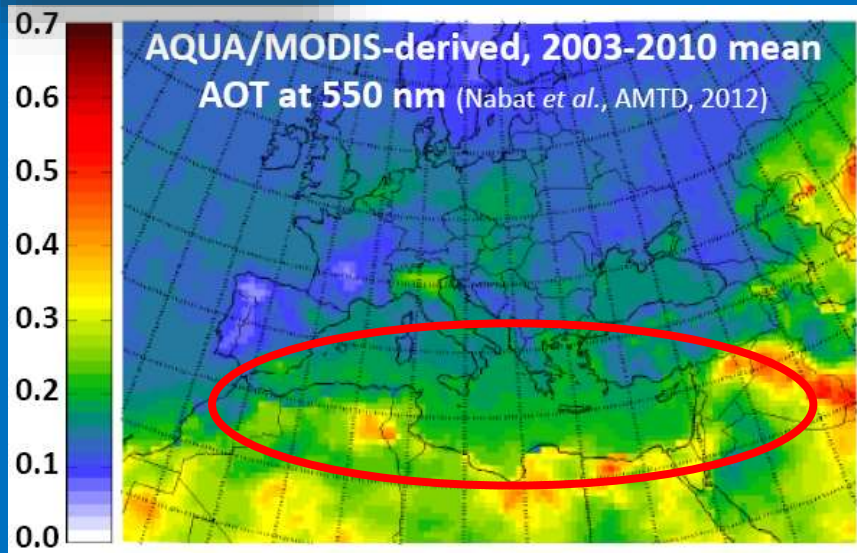
# Probability distribution (PDF) of daytime temperatures in summer (June – August)



- Models predict and analyse.
- How accurate they are?
- Measurements are required to check models validity

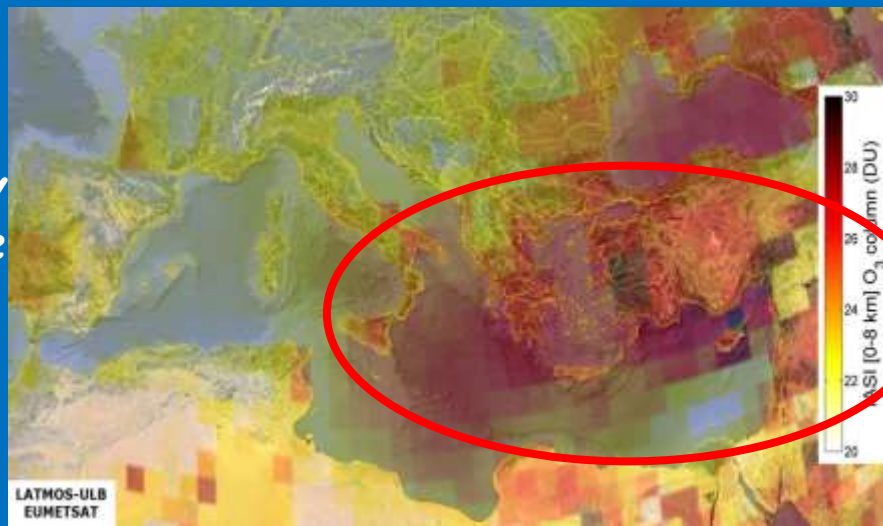


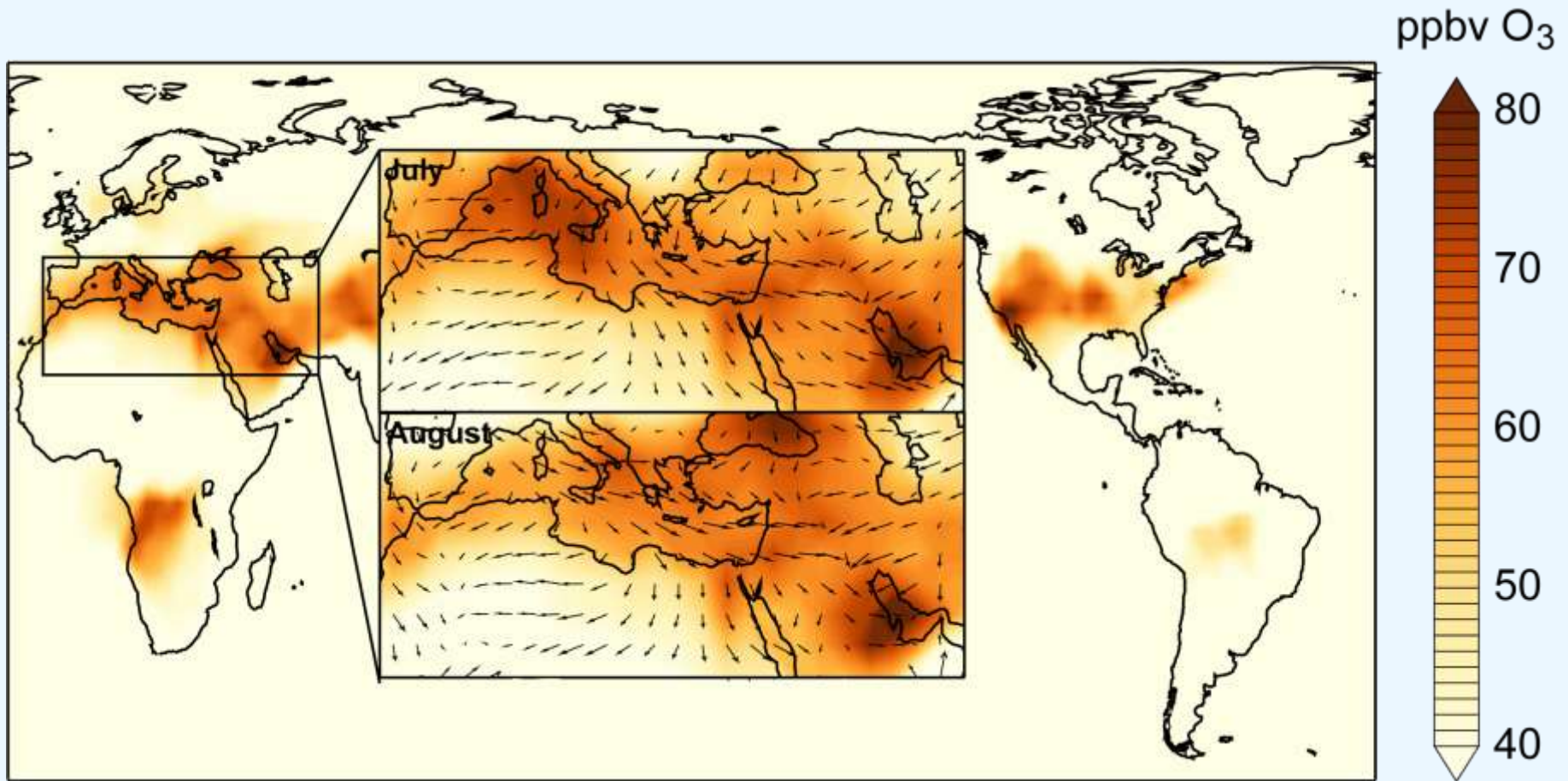
# *Air Pollution in the E. Mediterranean: As observed from satellites*



*A region having very high aerosol loading  
being responsible for large direct radiative  
forcing*

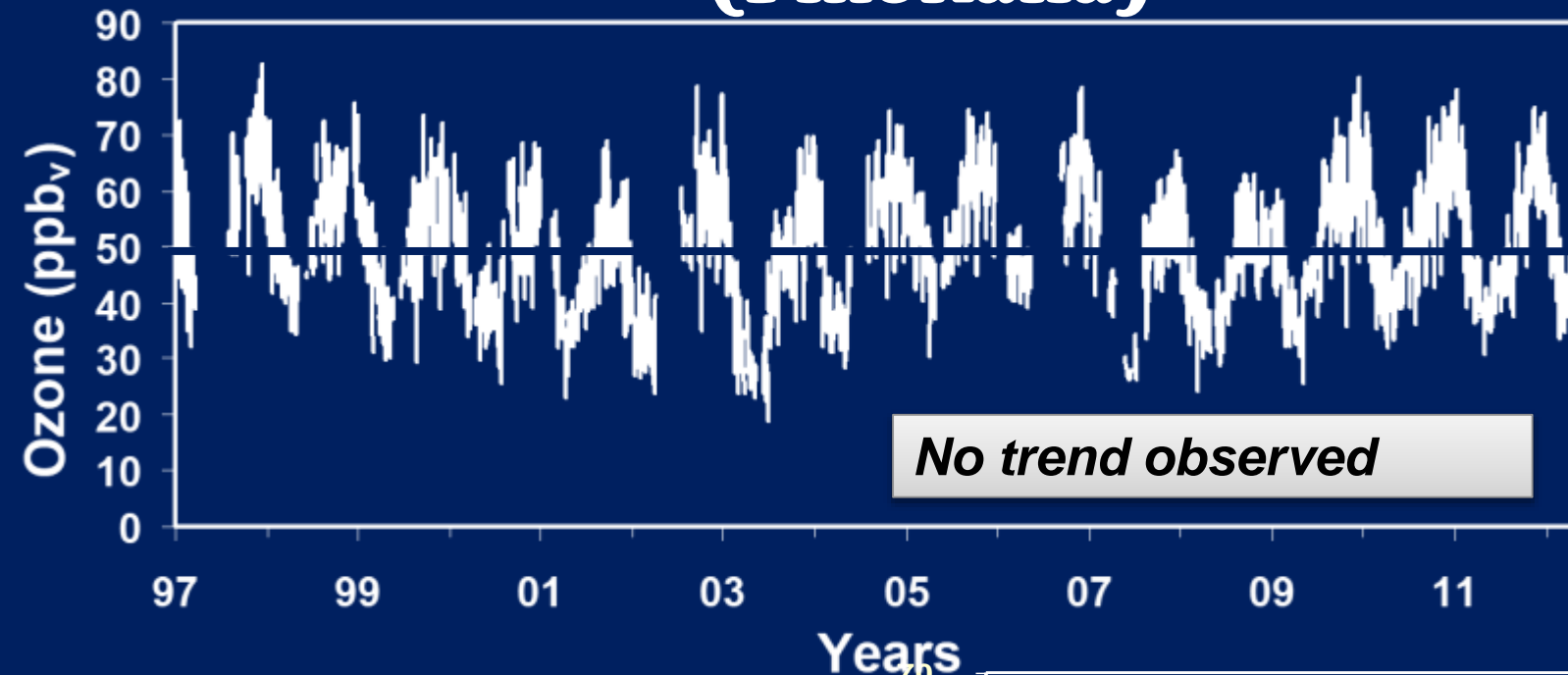
*A region having very high photochemistry  
reponsible for very high levels of ozone*



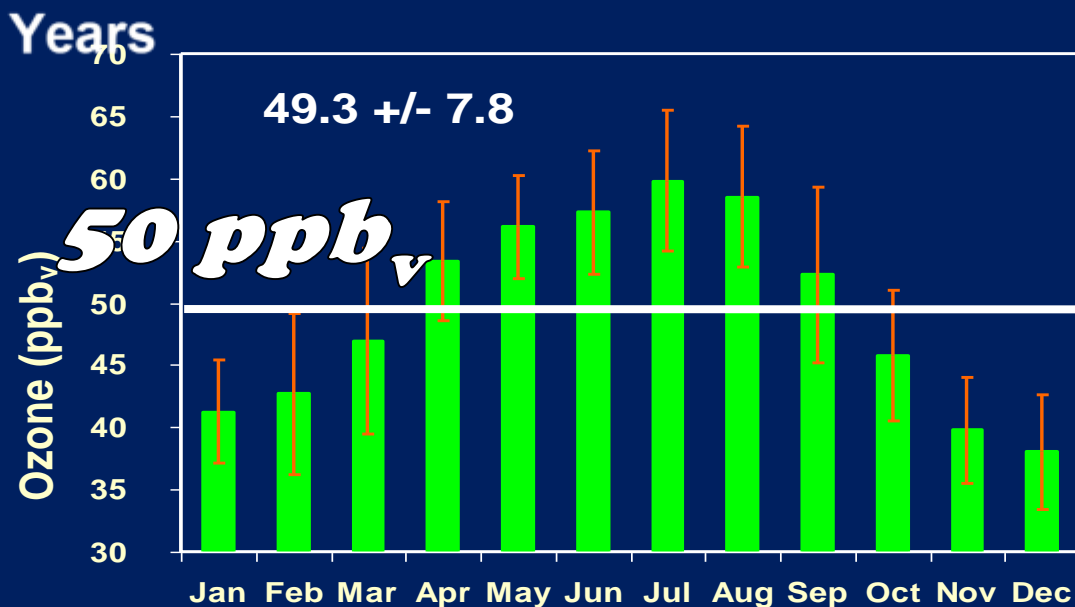


Ozone at the Earth's surface in summer (June – August)

# Trace gases characterization: Ozone (Finokalia)



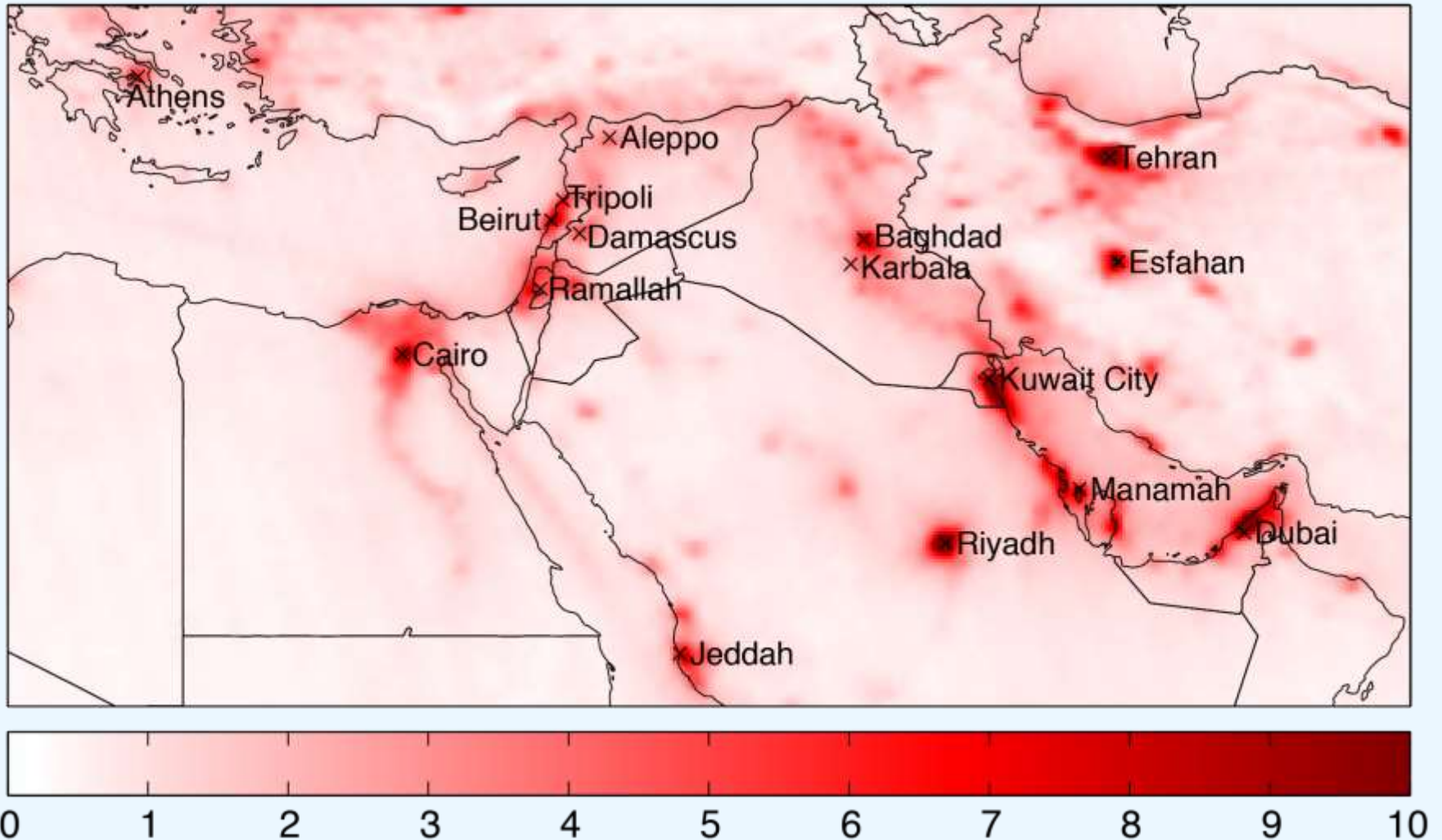
*Exceeding the 50 ppbv  
8h limit in Summer*





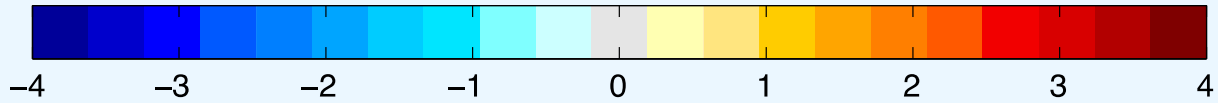
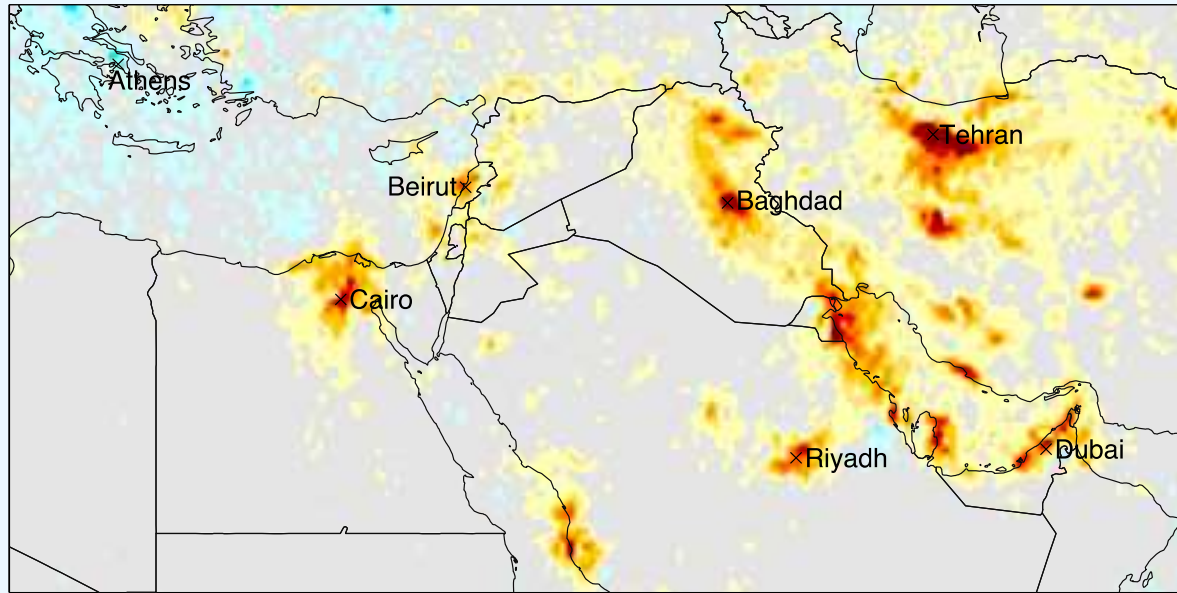
# Abrupt trend changes in atmospheric NO<sub>2</sub> observed from space

NO<sub>2</sub> column densities in 10<sup>15</sup> molecules/cm<sup>2</sup> during period 2005 – 2014

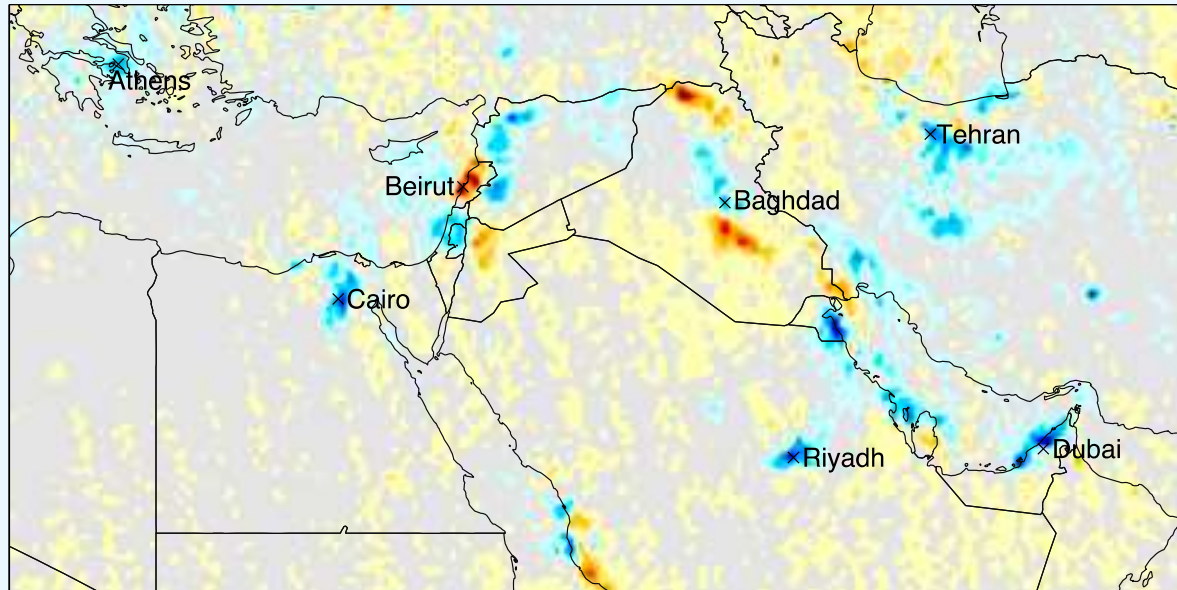


# NO<sub>2</sub> changes in 10<sup>15</sup> molecules/cm<sup>2</sup>

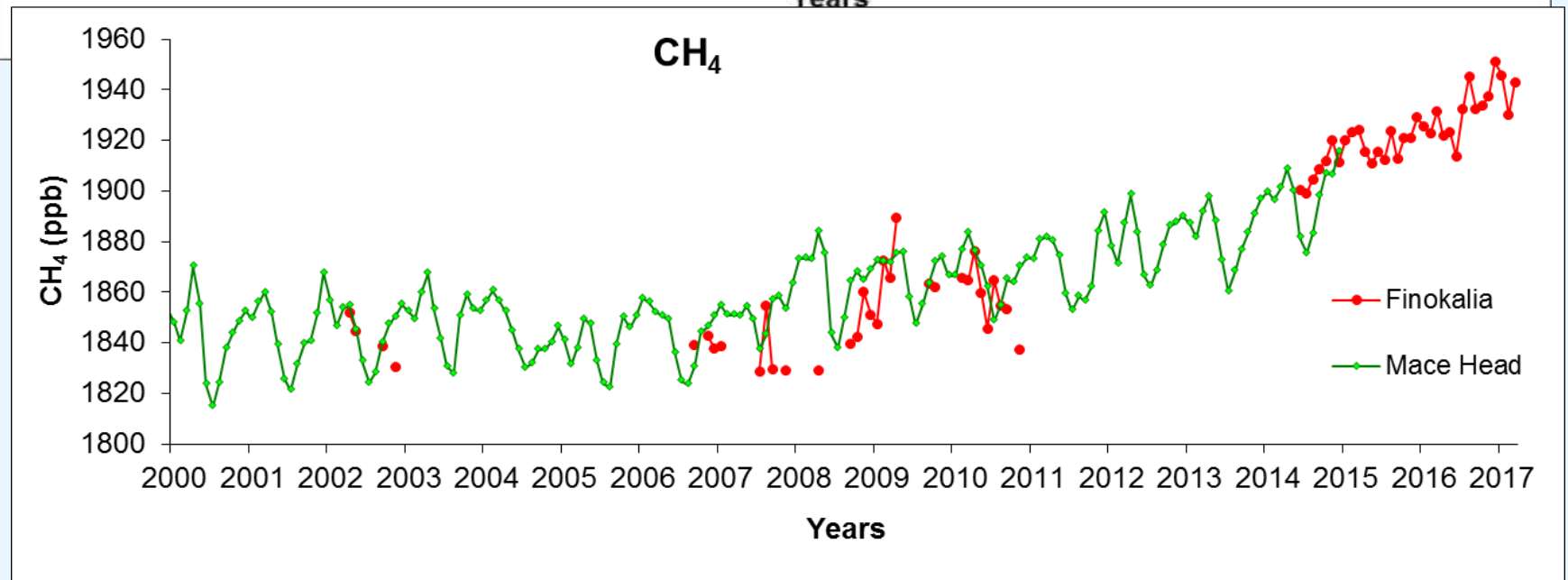
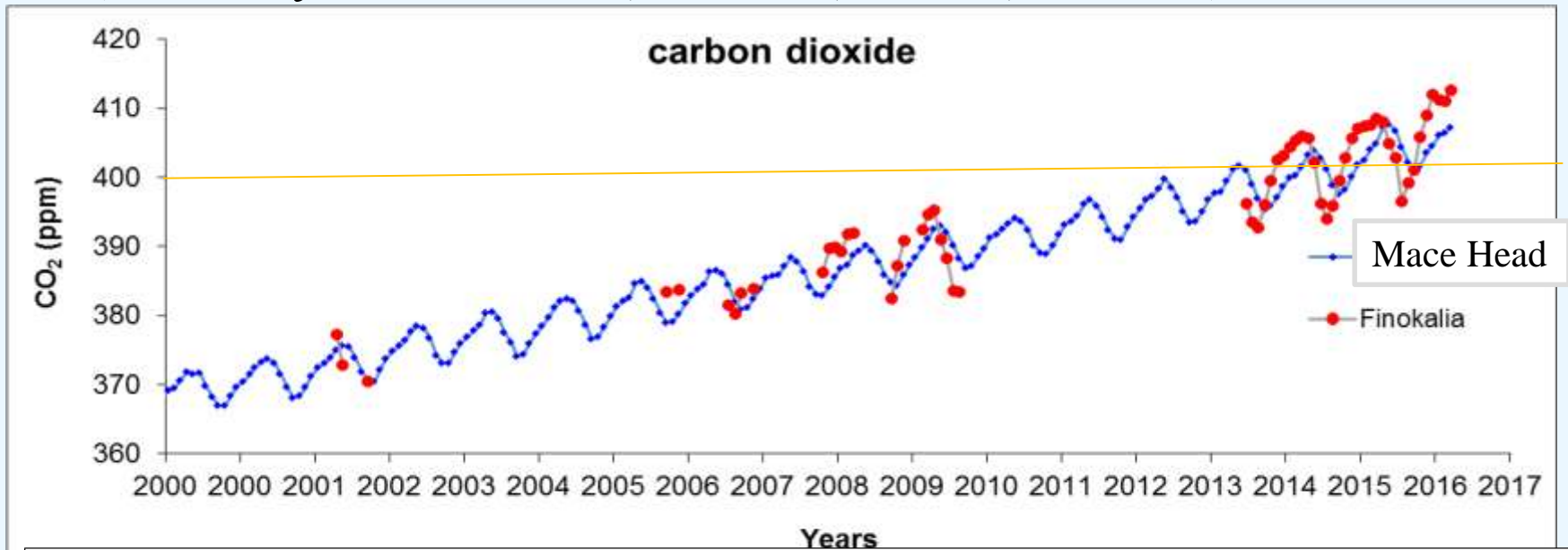
2005 to 2010



2010 to 2014



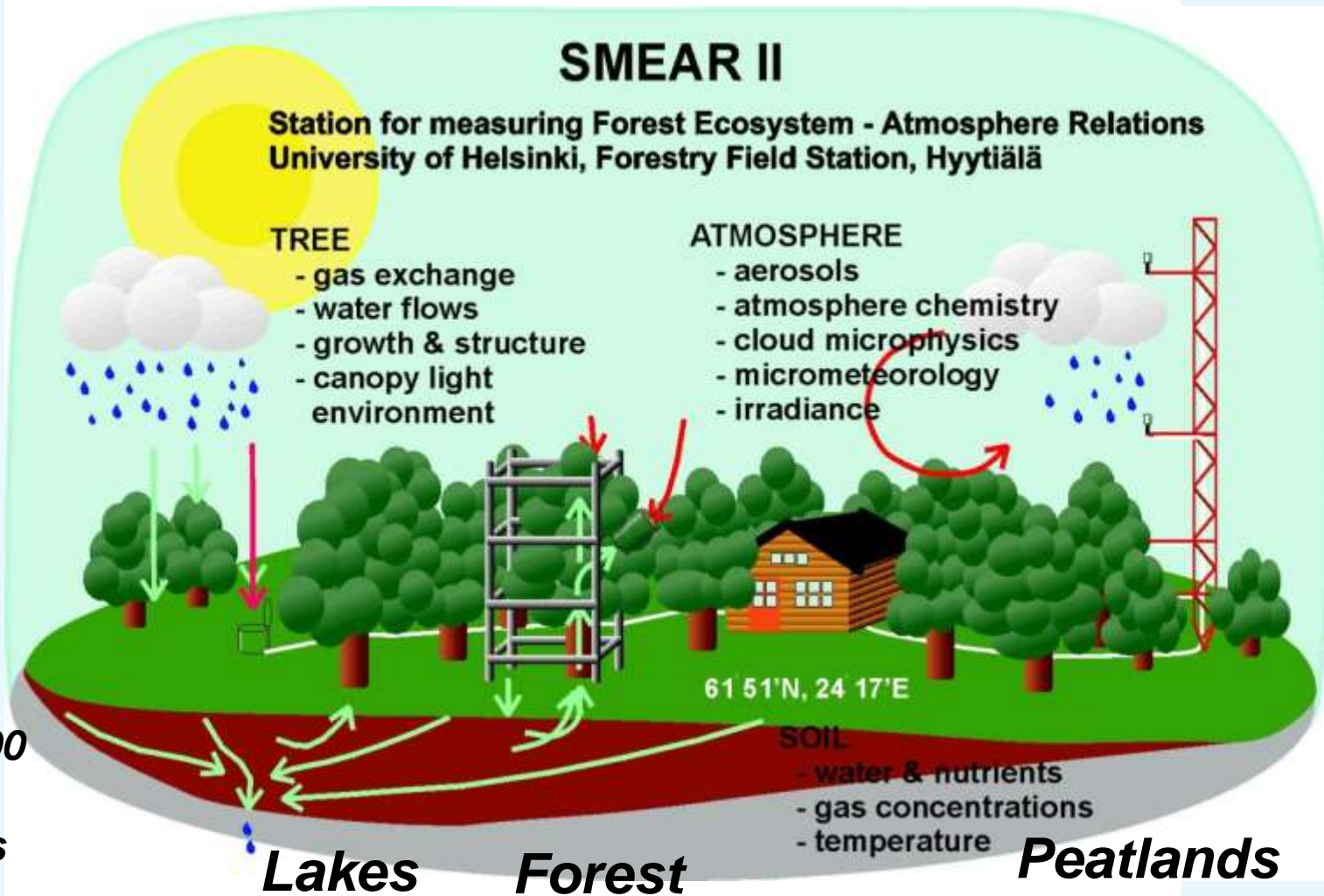
# Greenhouse gases measurements at Finokalia Crete (Courtesy M. Ramonet, P. Ciais, LSCE, France)



# The Mediterranean Atmospheric Network



# Continuous, comprehensive observations



Site for ICOS, ACTRIS, INGOS, EXPEER, ANAEE, LTEER, LifeWatch, WMO, EMEP, CARBOEUROPE, NITROEUROPE, EUCAARI, PEGASOS

Photos Juho Aalto

# ATMO- SPHERE

aerosols, atmospheric chemistry and physics, cloud microphysics, boundary layer micrometeorology, irradiance, deposition



# BIO- SPHERE

gas exchange, water and nutrient flows, biomass growth, canopy structure, energy capture and use



# LITO- SPHERE

water and nutrient concentrations and uptake, profiles of temperature and moisture, gas exchange, root growth, microbial processes



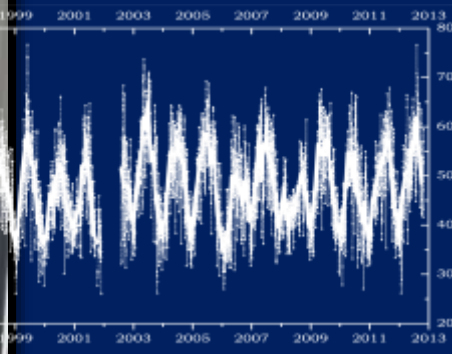
# HYDRO- SPHERE

gas and energy exchange, gas concentrations, dissolved org/inorg. carbon, phytoplankton biomass and composition, lateral fluxes, meteorology, catchment processes



**A FLAGSHIP STATION –**

# Monitoring stations

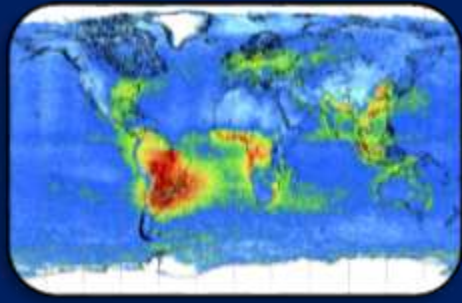
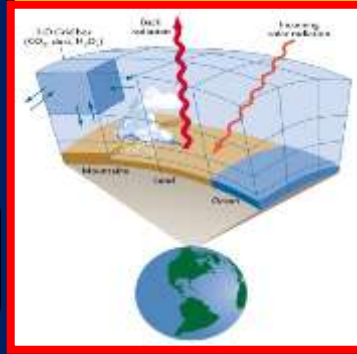


**Observations**

**Numerical Models**

**Airborne observations**

**Satellite observations**



# ***Conclusions***





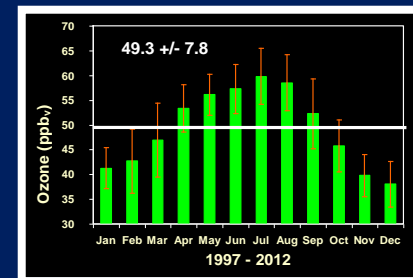
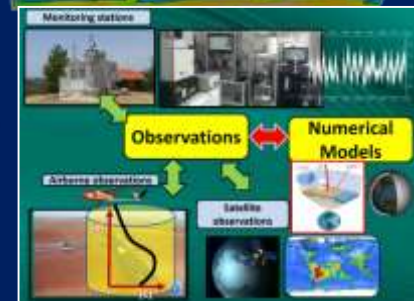
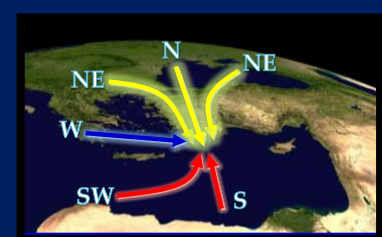
*Lower troposphere strongly polluted by European emissions*

*Upper tropospheric pollution from S-Asia even penetrates the lower stratosphere*

*Continuous monitoring of atmospheric composition using a combination of ground based stations, satellites and UAVs.*

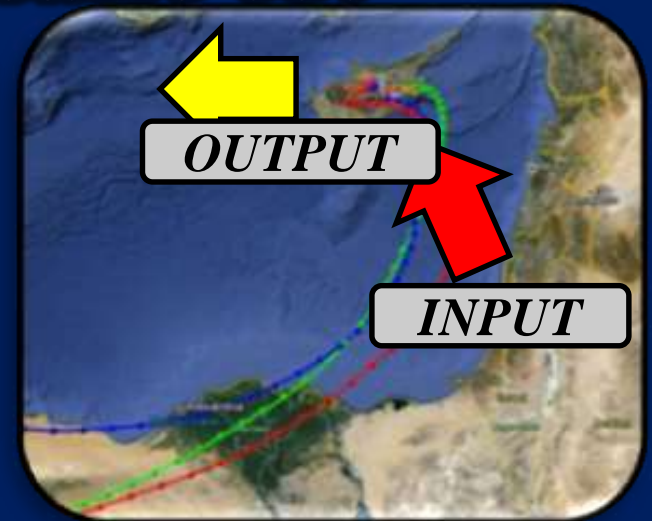
*Ozone 8-hourly air quality limit exceeded over entire Mediterranean throughout summer*

*Important health issue of aerosol levels around Mediterranean especially under severe dust events. Atmospheric pollution causes strong climate forcing.*



# ***It is thus important to:***

***Characterize the mechanisms controlling local and regional air pollution focusing on the sources, transport and transformations of trace species to the Mediterranean***



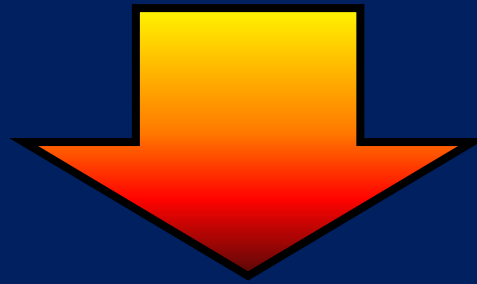
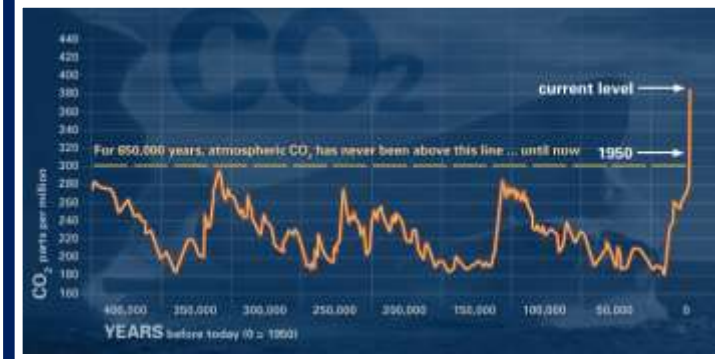
***Composition and origin of pollutants (particles and gases)***



***To understand the interactions and feedbacks between pollution, climate and human health.***



# Information needed **from all scales:** **TEMPORAL: Short → long term**



- 1. To understand**
- 2. To predict (*reducing uncertainties*)**
- 3. To provide evidence**
- 4. To propose mitigation strategies**

# MULTIDIMENSIONAL, MULTIDISCIPLINARY, MULTISCALE APPROACH TO ANSWER GRAND CHALLENGES

*Clear and ambitious vision / from deep understanding to practical solutions*

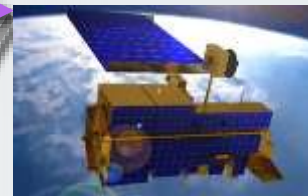
*Empirical measurements and modelling / from observations to new theories*

*From research to innovations / economic growth and human wellbeing*

**Ground-based**



**Satellite**



*Provides details*

**CURRENT STATE**

*Provides context*

• **Initial Conditions**

• **Assimilation**



**Multiscale  
Models**

*Complete the picture*

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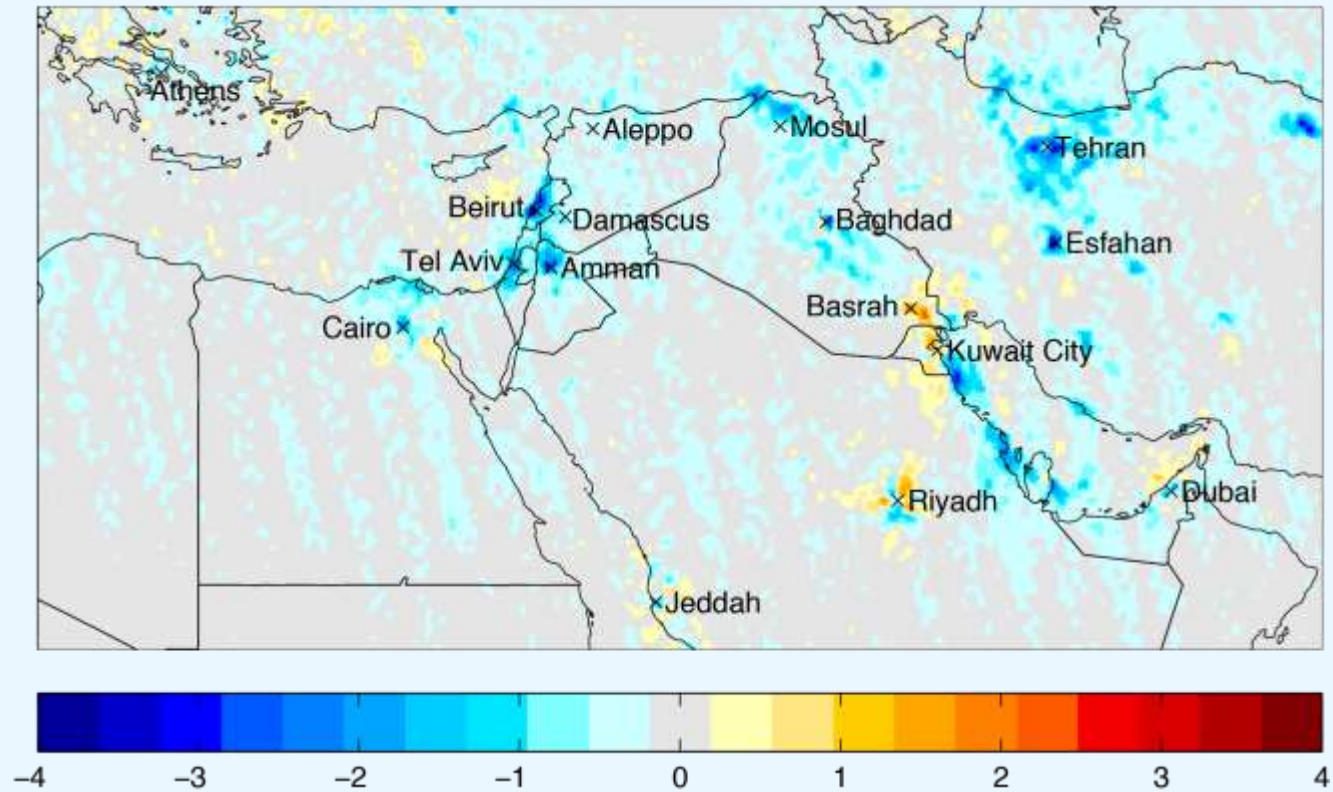
*Heraklion, Crete - Greece*

# Premature mortality attributable to air pollution

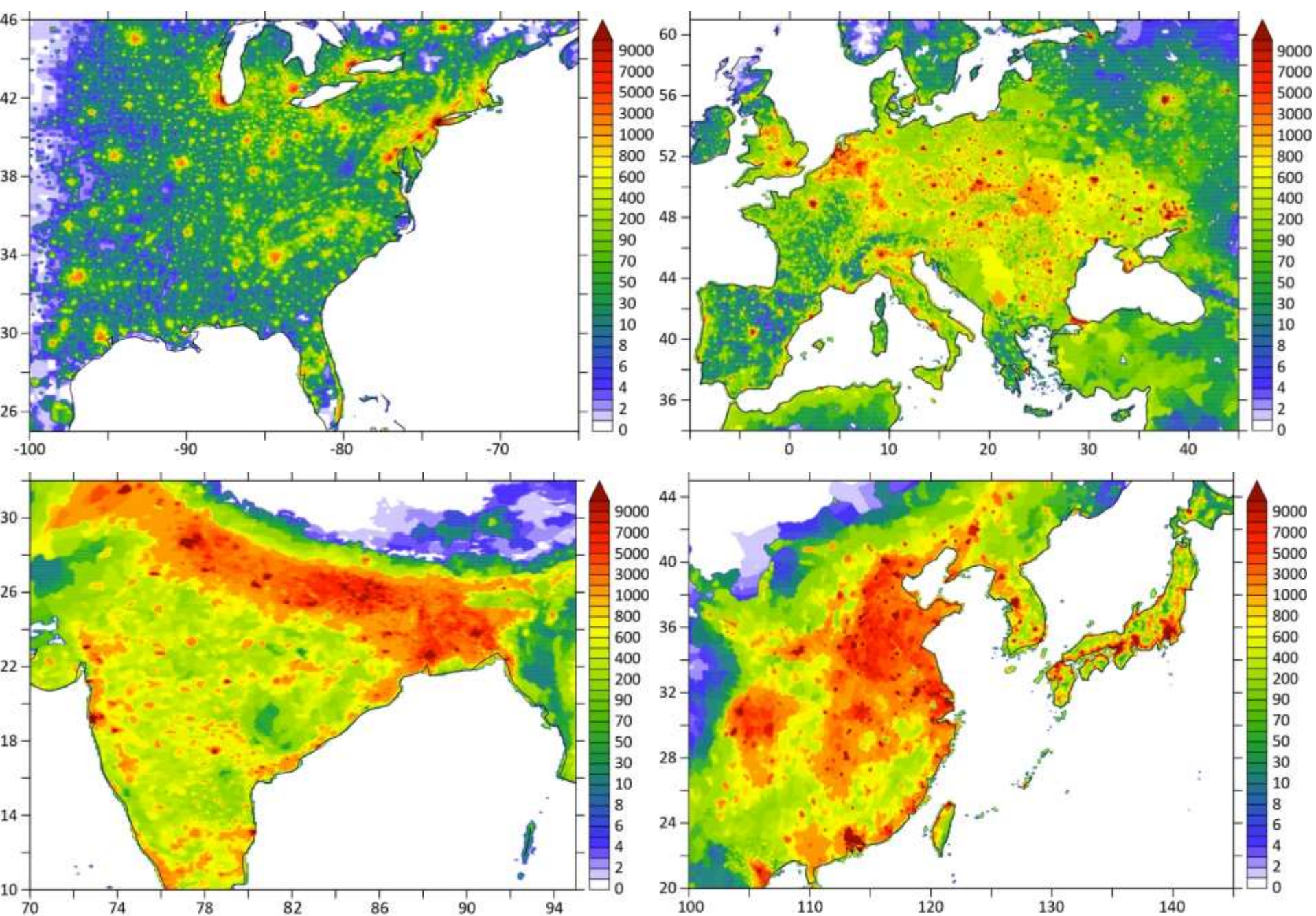
PM <sub>2.5</sub> mortality	<b>3.16 M/yr</b>
O <sub>3</sub> mortality	<b>0.14 M/yr</b>
Total	<b>3.30 M/yr</b> (95%CI = 1.61 – 4.81 M/yr) (statistical uncertainty $\pm 50\%$ )

Cerebrovascular disease (stroke)	1.31 M/yr
Ischemic heart disease (heart attack)	1.08 M/yr
Chronic obstructive pulmonary disease	0.52 M/yr
Lung cancer	0.16 M/yr
Acute lower respiratory illness (<5 years)	0.23 M/yr

2014 to 2015



NO<sub>2</sub> changes in 10<sup>15</sup> molecules/cm<sup>2</sup>

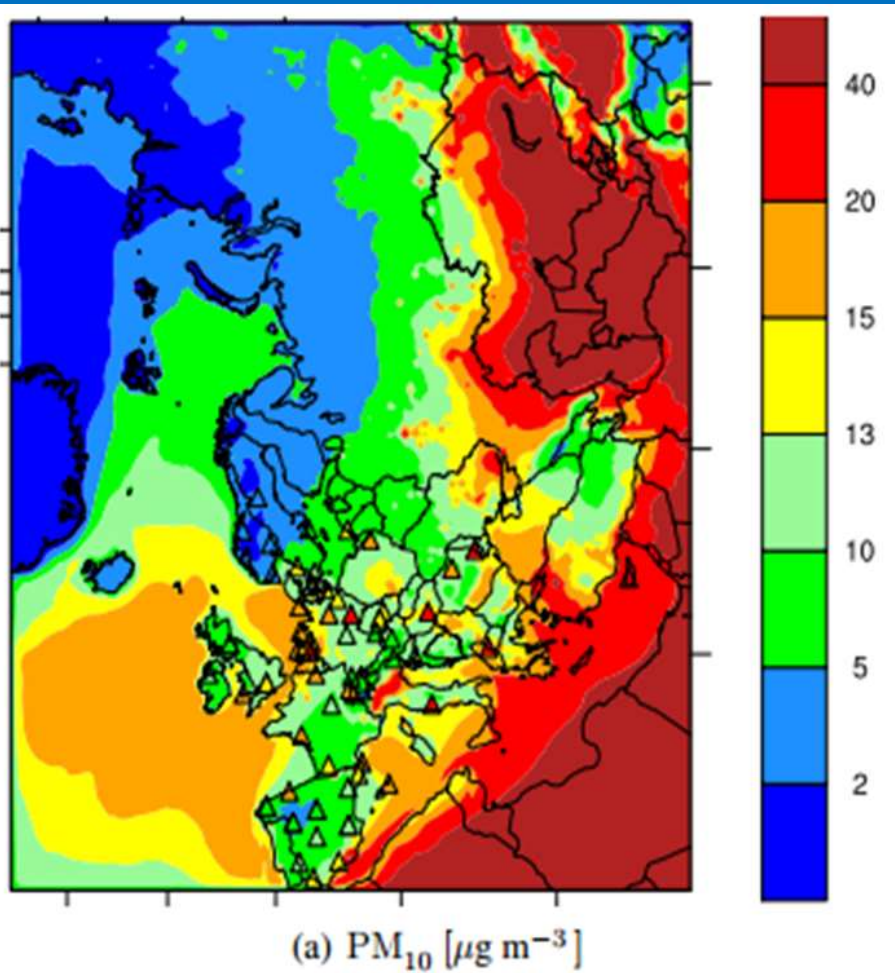


Annual mortality attributable to air pollution (individuals per  $100 \times 100 \text{ km}^2$ )



# EU legislation on $PM_{2.5}$ and $PM_{10}$

*Annual mean (2013) concentrations of  $PM_{10}$  calculated with the EMEP/MSC-W model (colour contours) and observed at EMEP monitoring network*



*Annual EU limit  $PM_{10} =$*

*$40\mu\text{g}/\text{m}^3$*

*In the Southern Europe  $PM_{10}$  are elevated and any extra (small) PM emissions may put PM10 above EU limits*