ATMOSPHERIC POLLUTION IN THE MEDITERRANEAN: SOURCES AND IMPACT ON AIR QUALITY, HEALTH AND CLIMATE

Nikos Mihalopoulos

University of Crete

National Observatory of Athens

IERSD - NOA

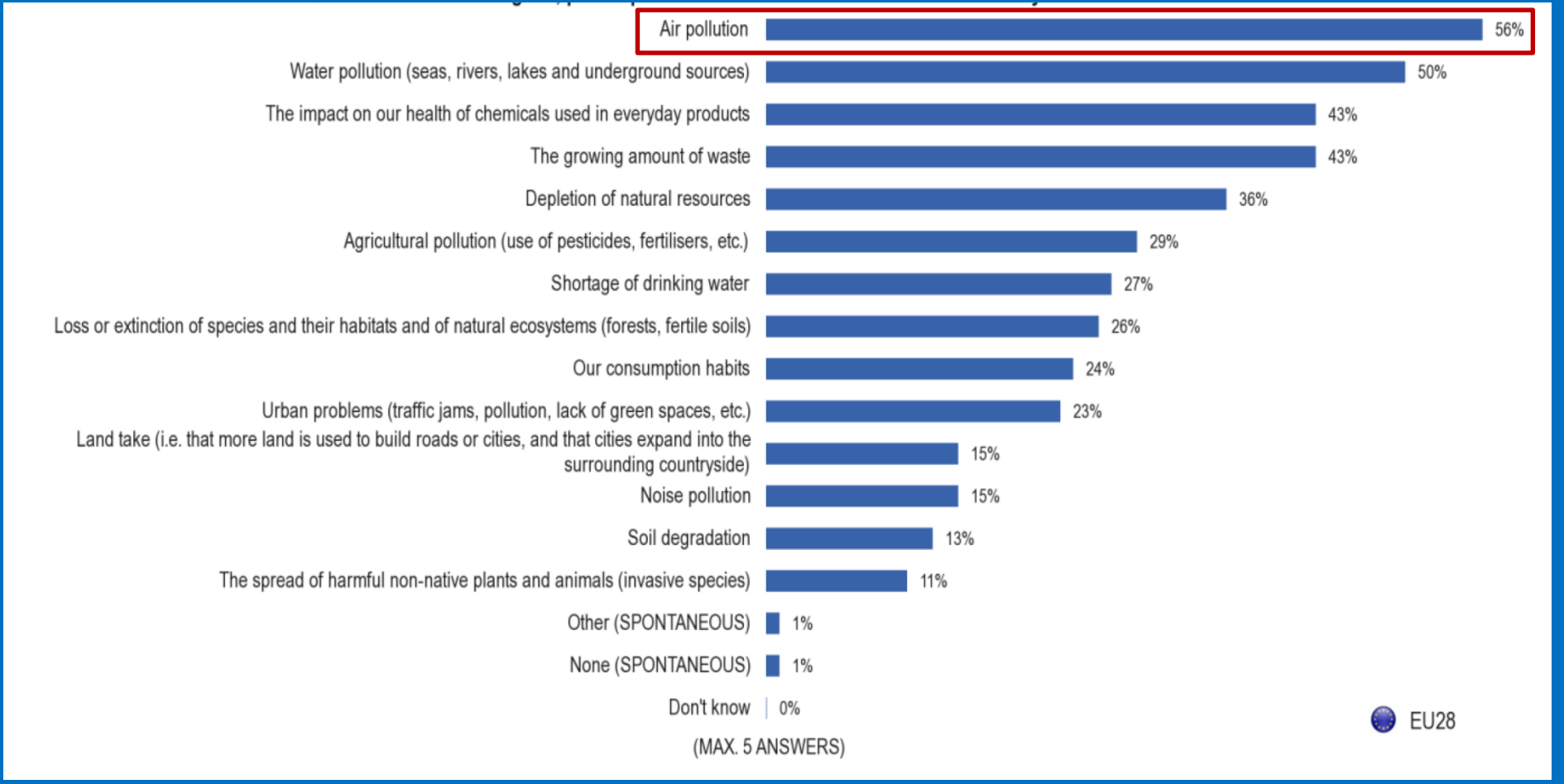
Thanks to

- *Profs. J. Lelieveld (MPI, Germany), J. Sciare (CyI, Cyprus), M. Vrekoussis (Bremen, Germany)*

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

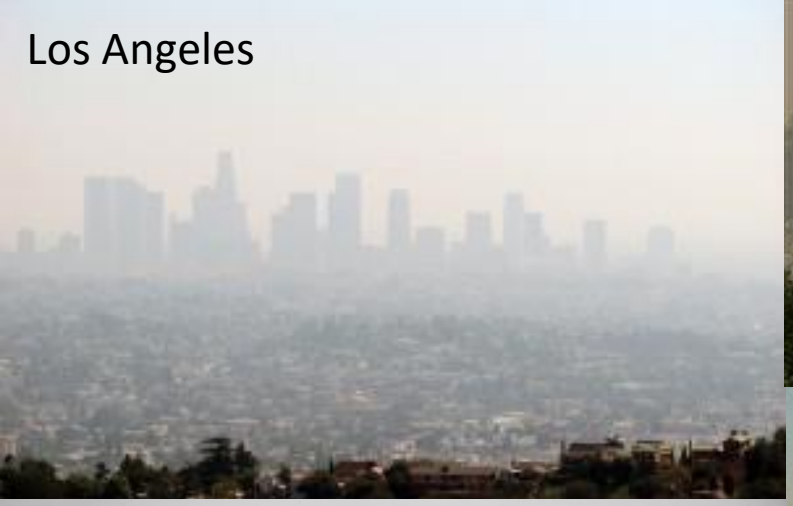
The **Anthropocene** is proposed as the new geological epoch where **human-influence will dominate the fossil records**. There is overwhelming global evidence that atmospheric, geologic, hydrologic, biospheric and other Earth system processes are now modified by human activity. (E. F. Stoermer and P. J. Crutzen 2001 IGBP)[Slide courtesy of J.P.Burrows]

Air pollution : First environmental concern of EU citizens



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

Los Angeles



Athens

Sao Paulo

Beijing

Singapore

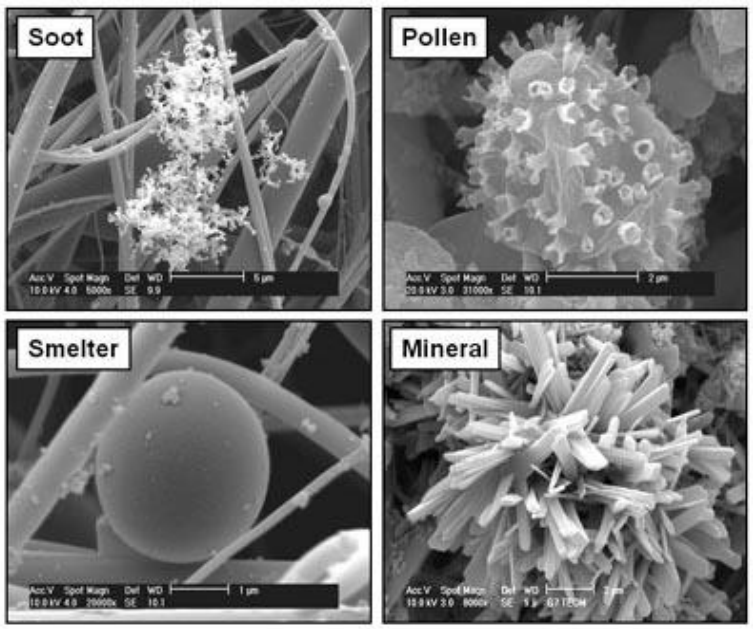
Mexico City

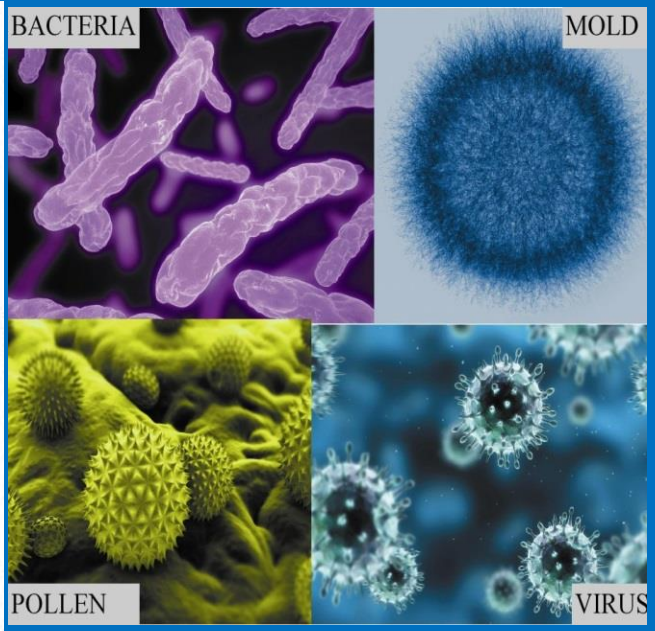
Air pollution : What are we talking about ?

Anthropogenic

versus

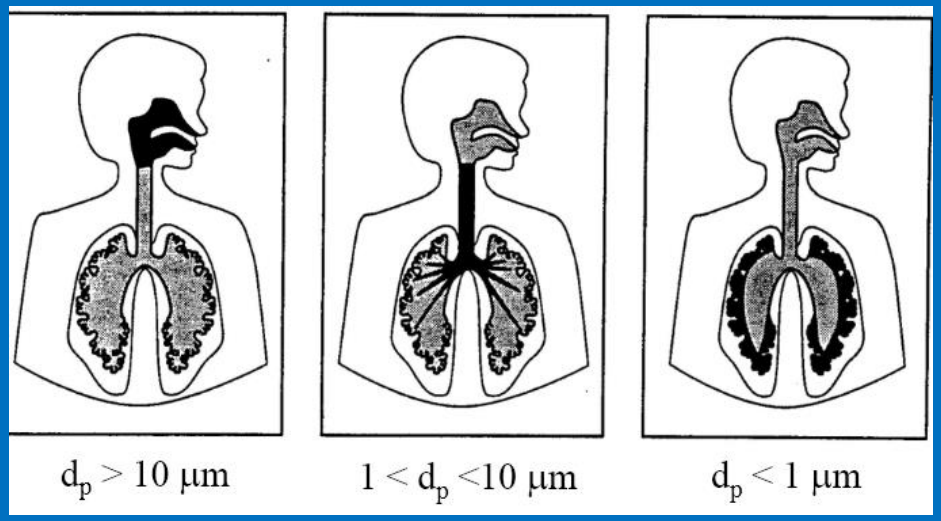
Natural





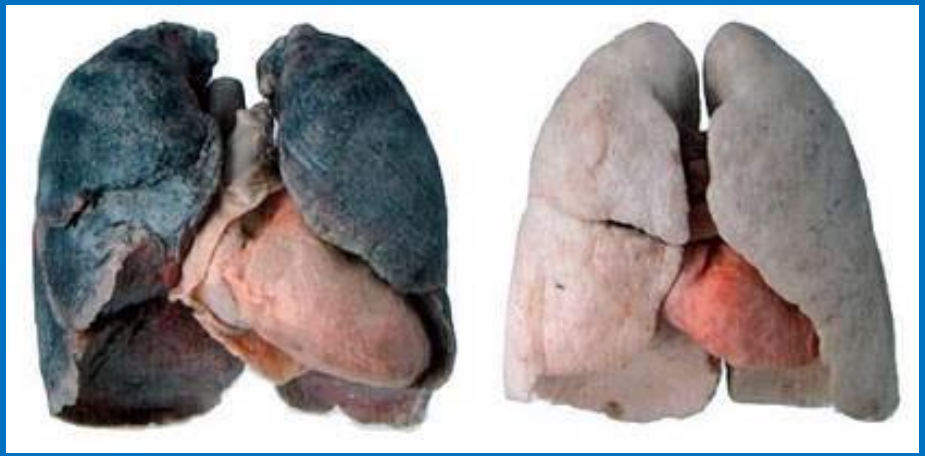
Sources ?

Aerosols : Health impact (1/2)



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

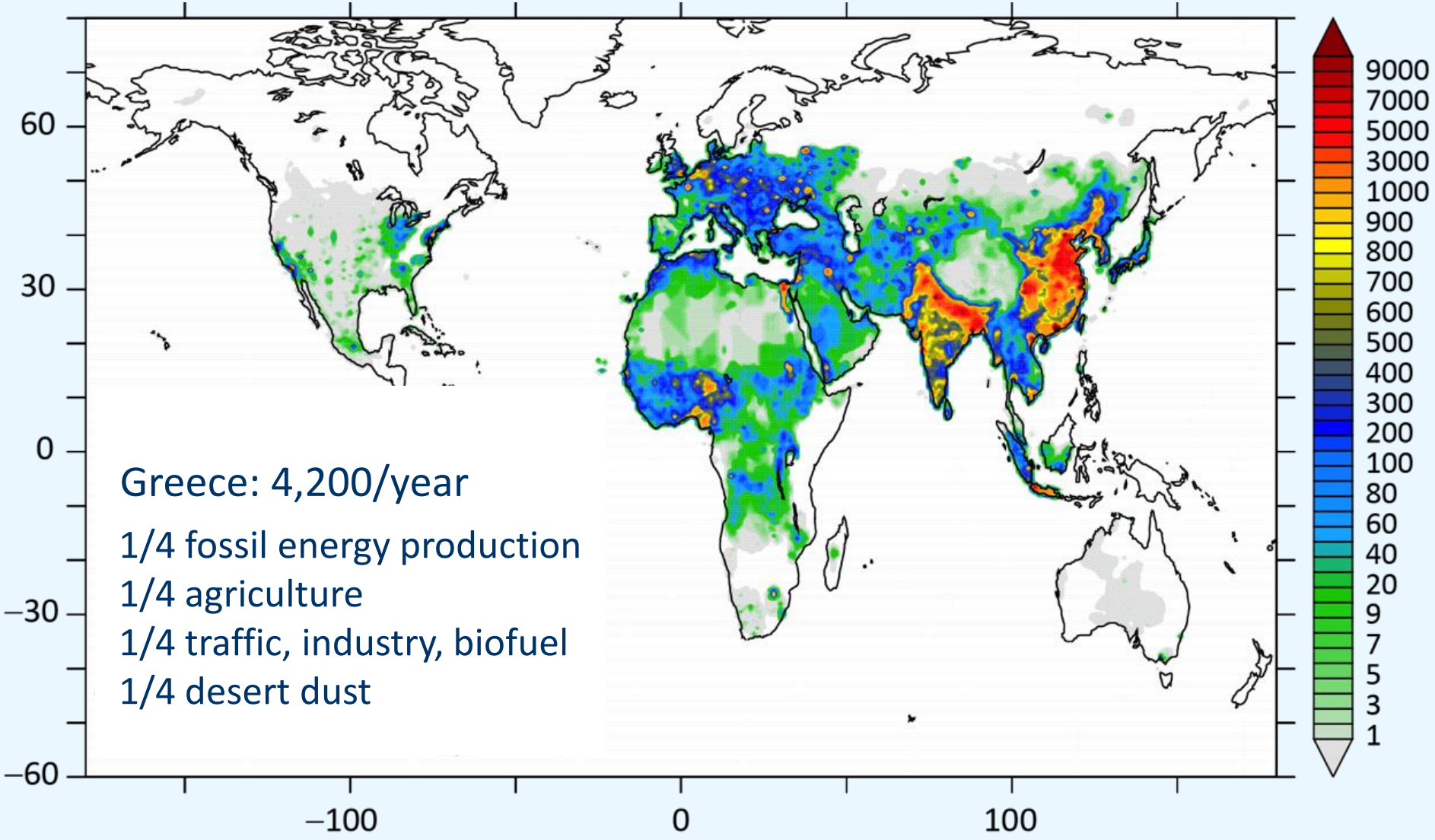
✓ *The surface area of human lungs in contact with ambient air is equivalent to the superficy of a tennis court*



✓ *In polluted areas, Black Carbon are among the smallest particles (< 100nm) and have been classified recently by WHO as cancerogenic*

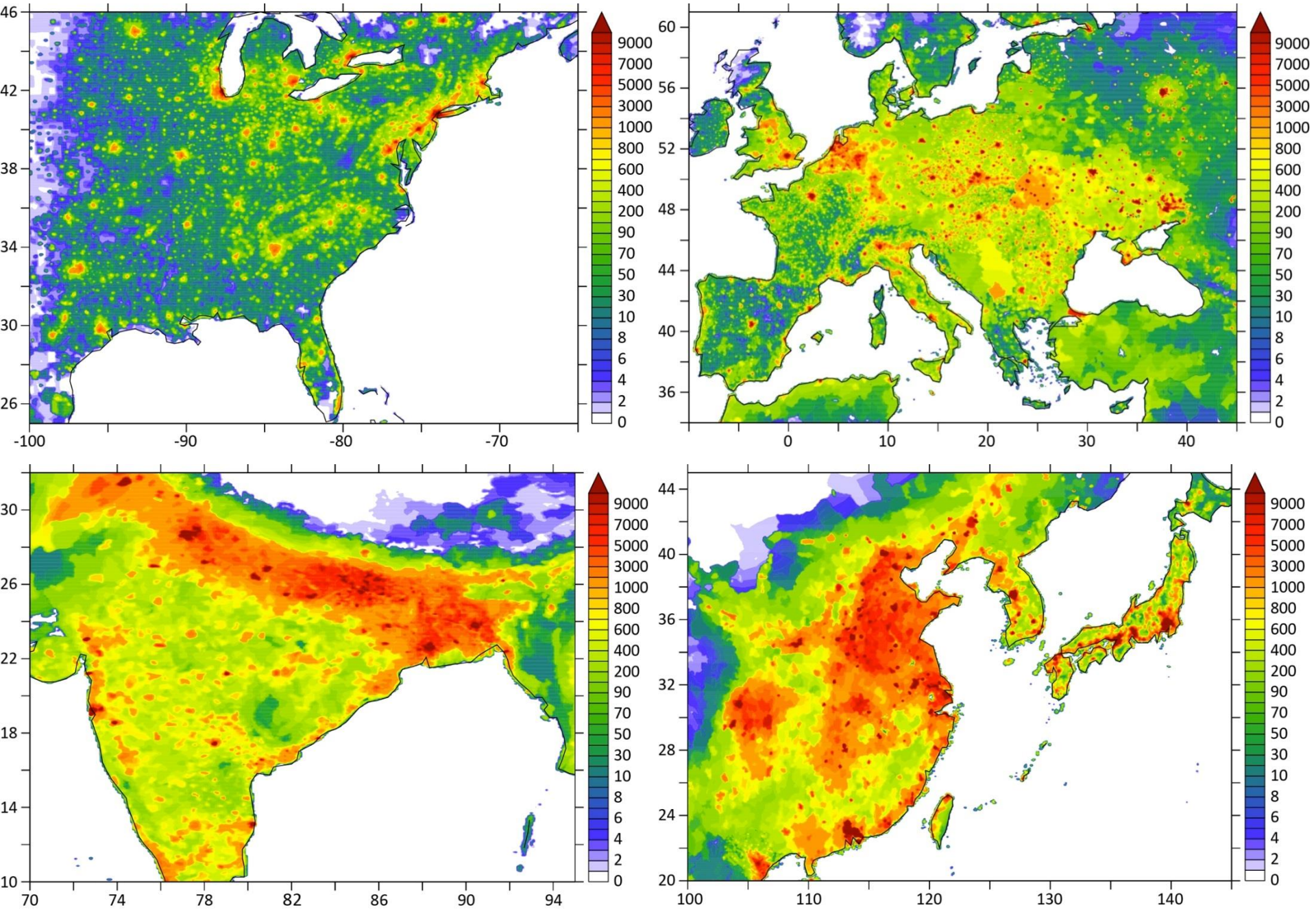
Annual premature mortality attributable to air pollution

Individuals per 100 × 100 km^2 – Globally 3.3 million/year



Greece: 4,200/year

1/4 fossil energy production
1/4 agriculture
1/4 traffic, industry, biofuel
1/4 desert dust



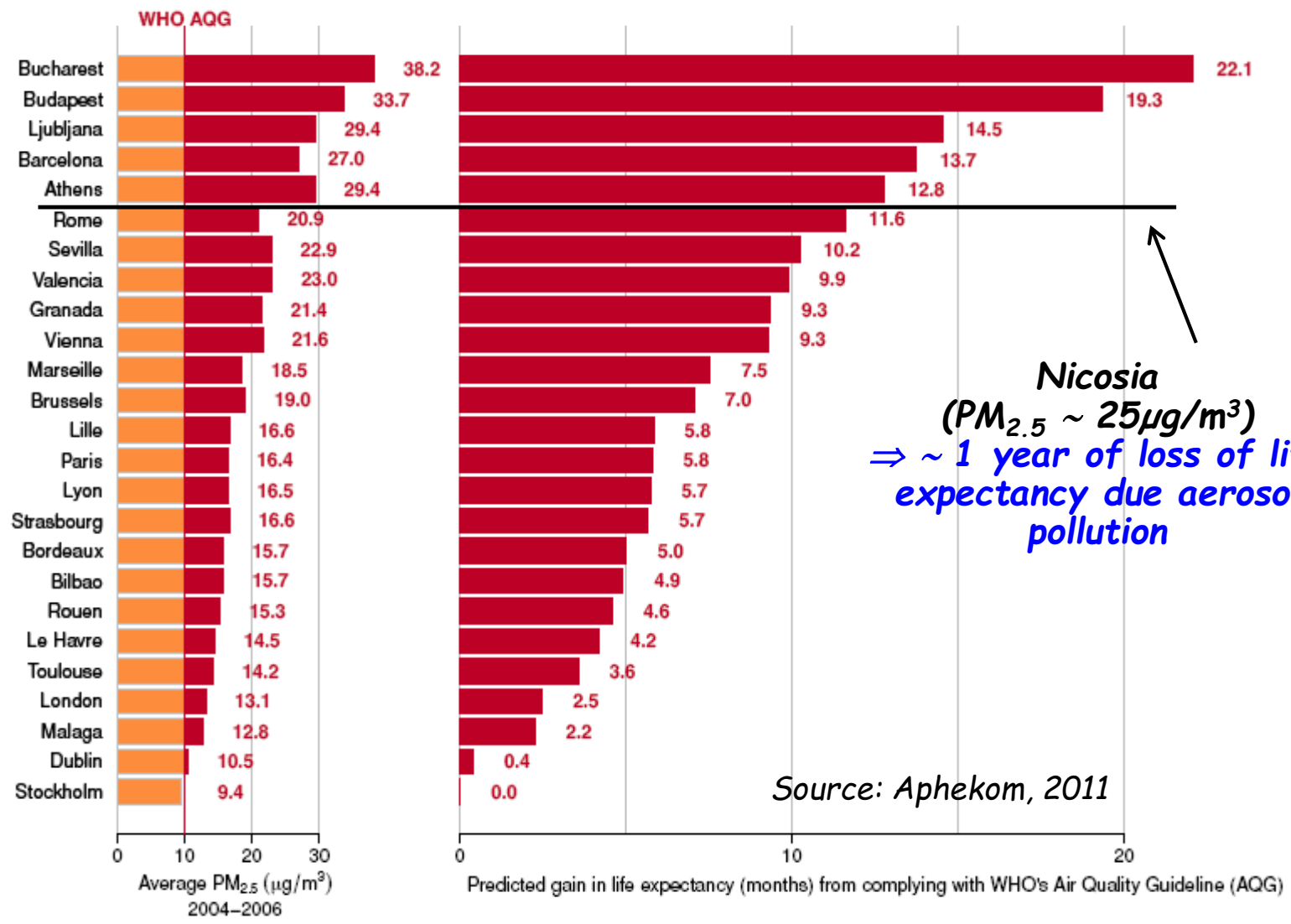
Annual mortality attributable to air pollution (individuals per 100 × 100 km^2)

Premature mortality attributable to air pollution

$PM_{2.5}$ mortality	**3.16 M/yr**
O_3 mortality	**0.14 M/yr**
Total	**3.30 M/yr** (95%CI = 1.61 – 4.81 M/yr) (statistical uncertainty ±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

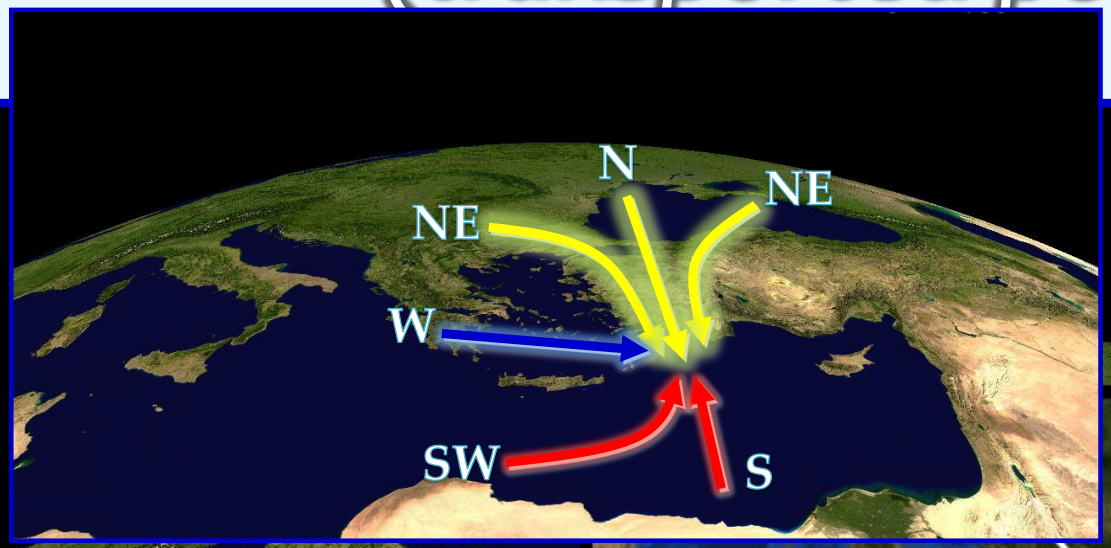
Aerosols : Health impact (2/2)



Nicosia
($PM_{2.5}$ ~ 25µg/m³)
⇒ ~ 1 year of loss of life expectancy due aerosol pollution

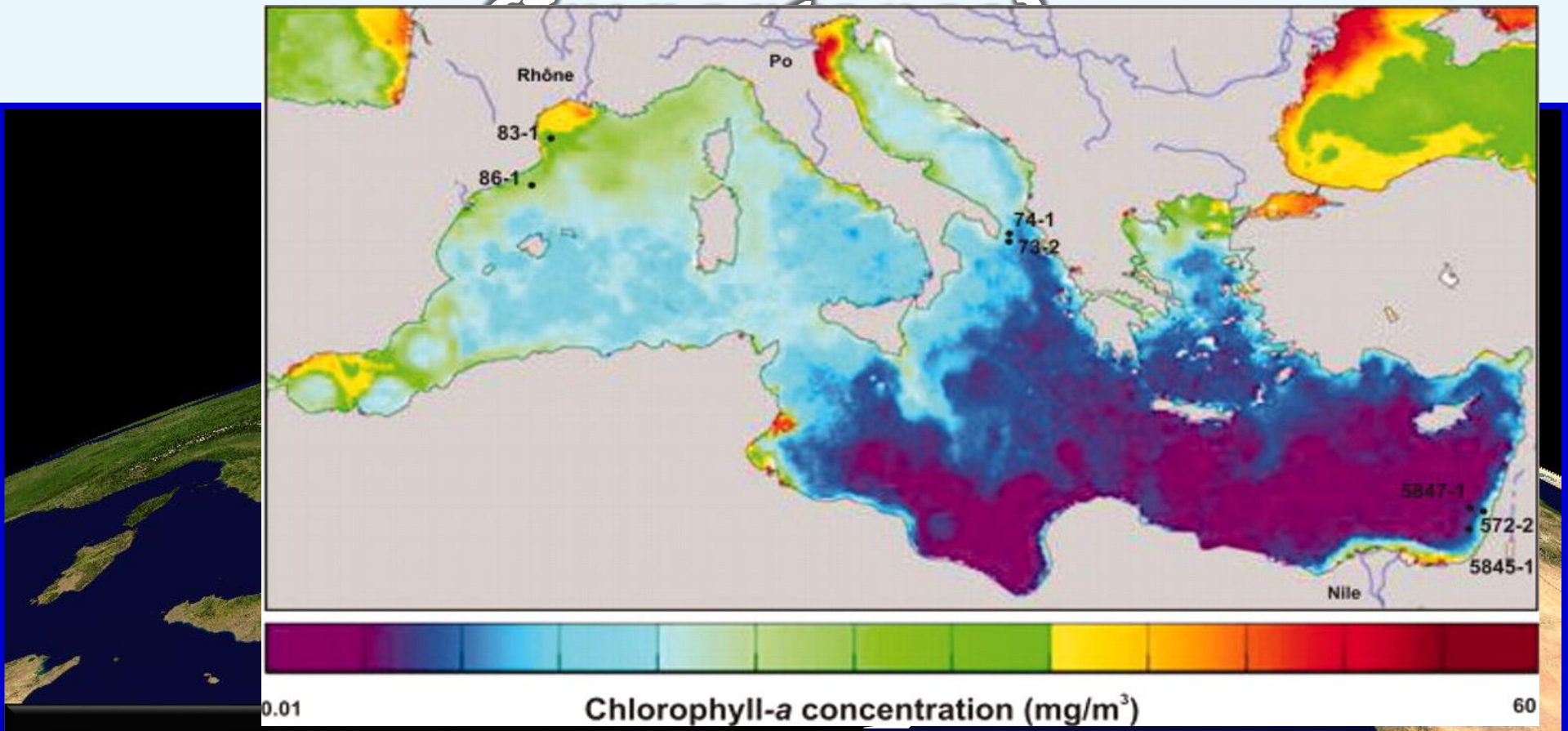
Mediterranean region

Why the Mediterranean region? (transported pollution)



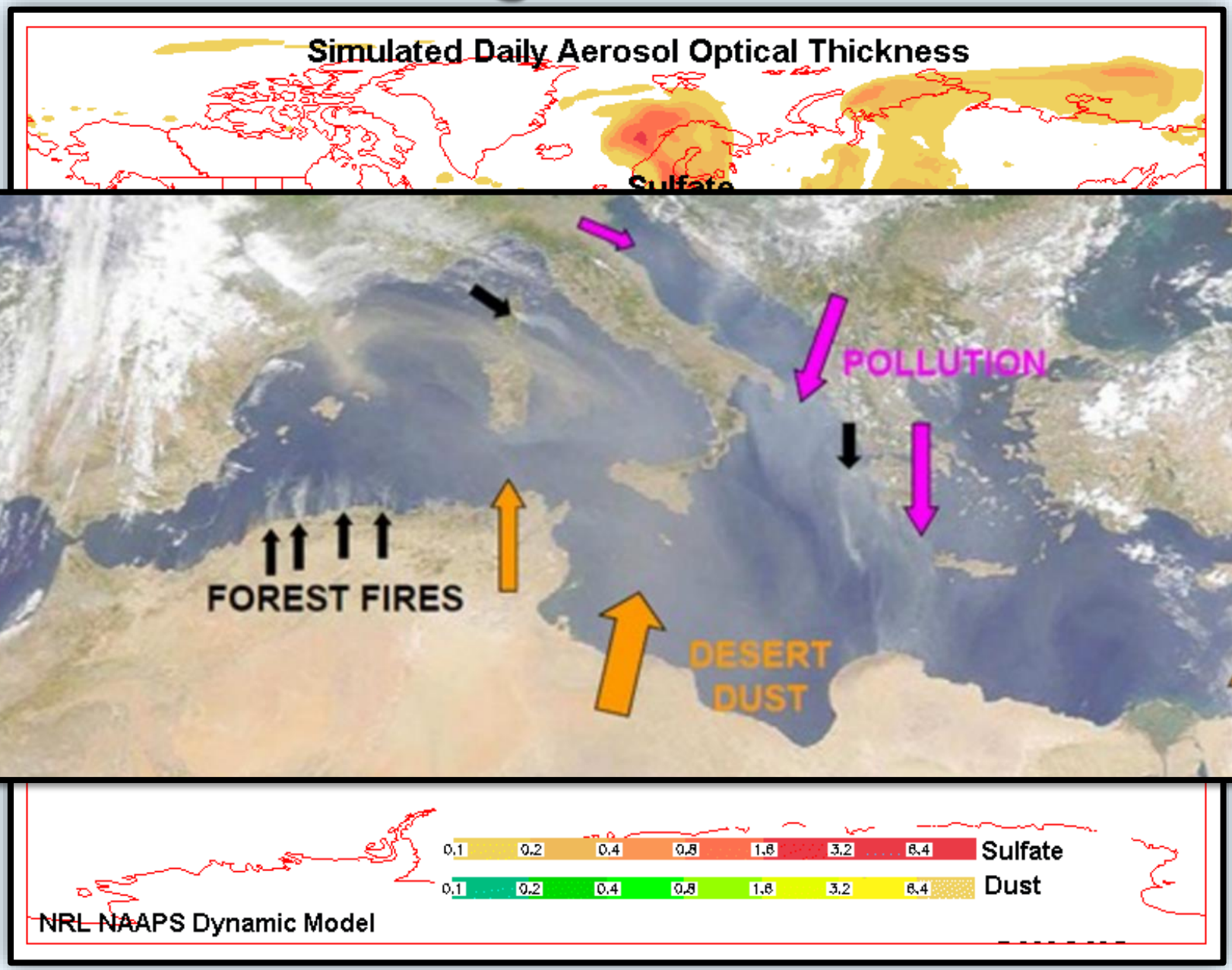
Strong influences by air pollution transport

Why the Mediterranean region?

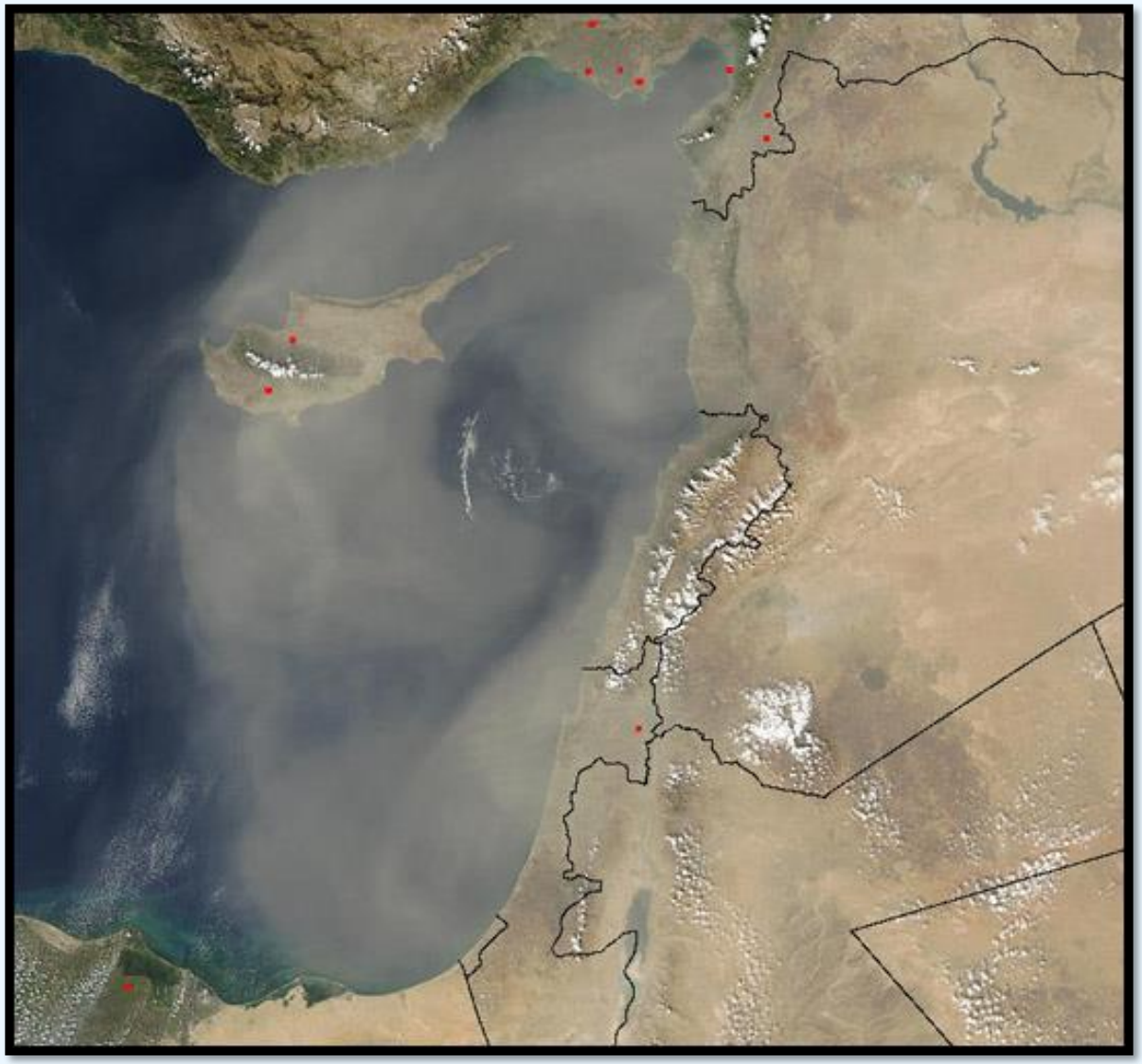


Small-scale coupled ocean-atmosphere system

Mixture of pollution sources

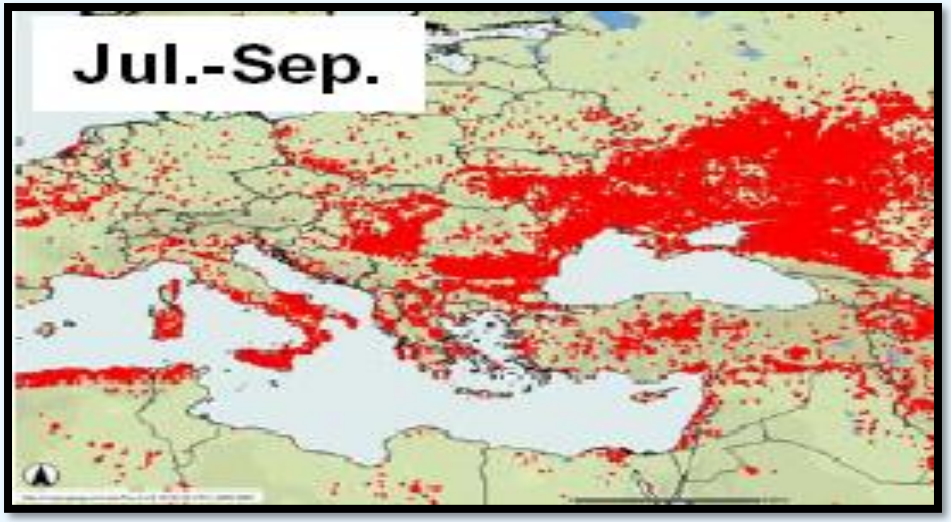


Why the Mediterranean region? Frequent dust events



Why the Mediterranean region? (biomass burning)

Seasonal variation of biomass burning sources around E. Mediterranean



Evidence:

Seawifs satellite pictures of Greek fires in Peloponissos (July 13th, 2000) and Samos Island (July 14th, 2000)

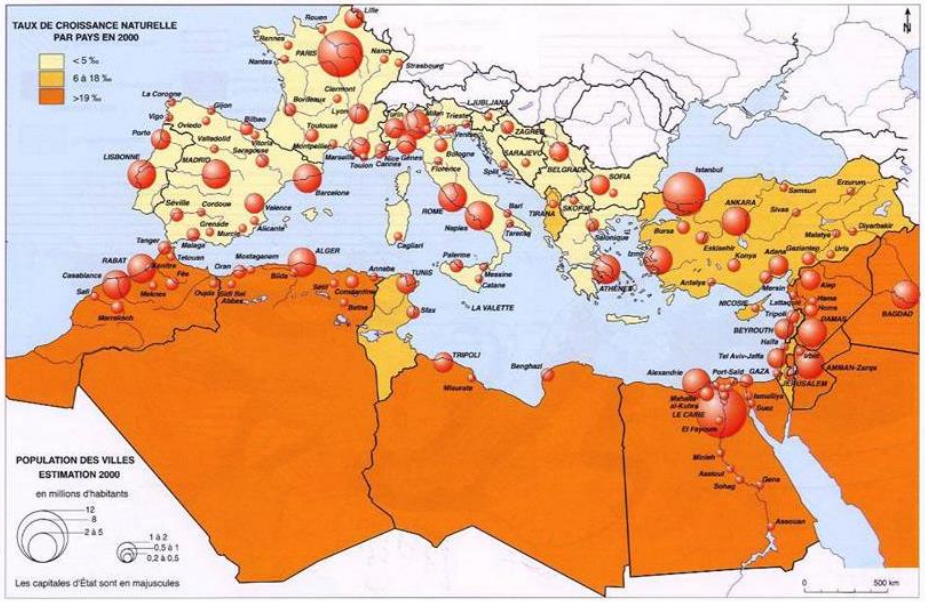
July, 13th 2000

July, 14th 2000

Sciare et al. ACP, 2003

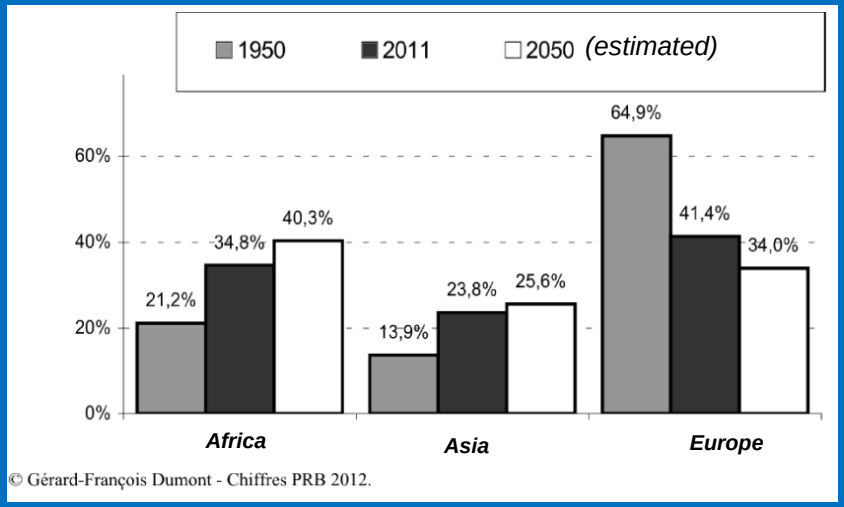
Human exposure to air pollution in the Mediterranean

Population around the Mediterranean (2000)

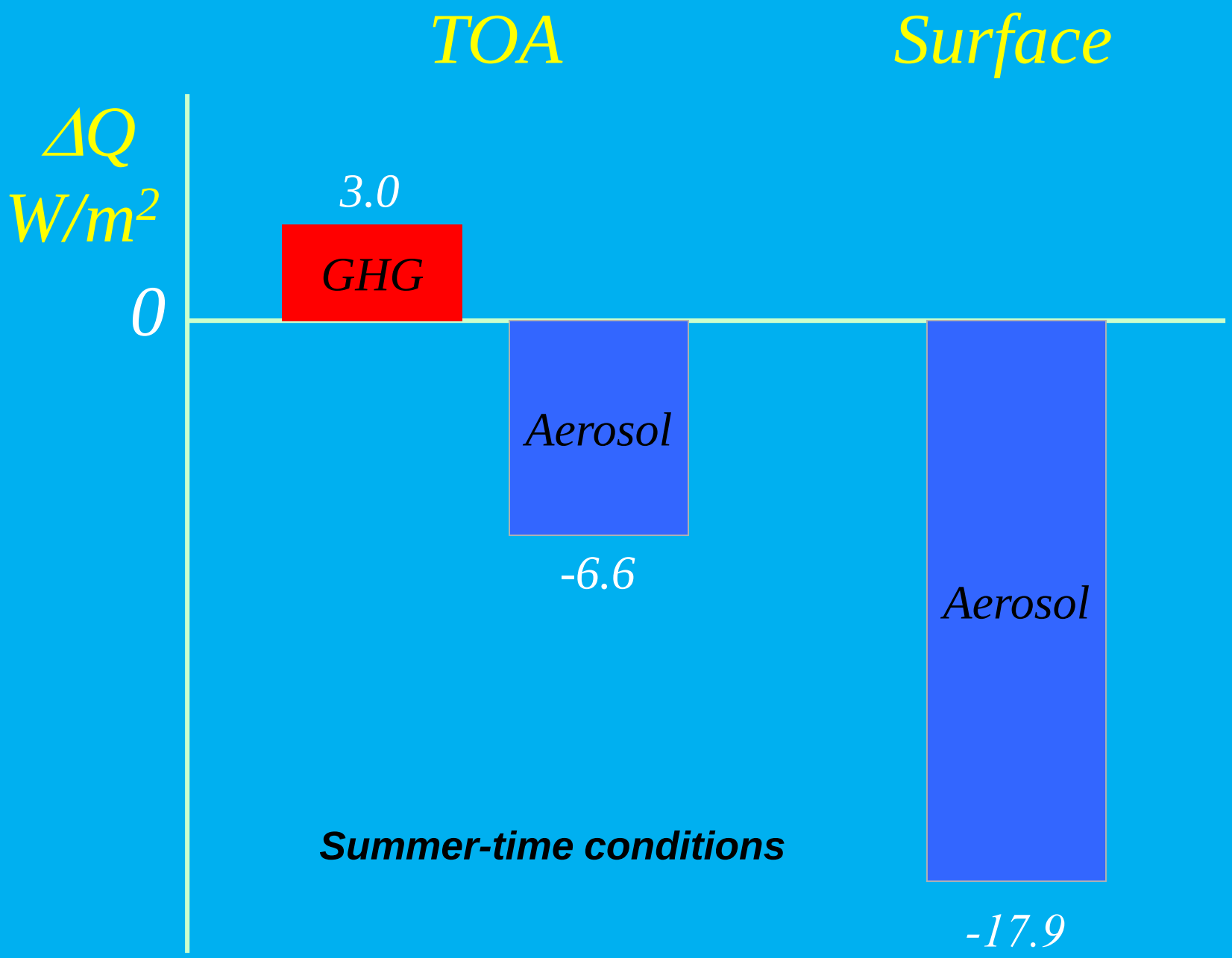


(Source: Géopolis)

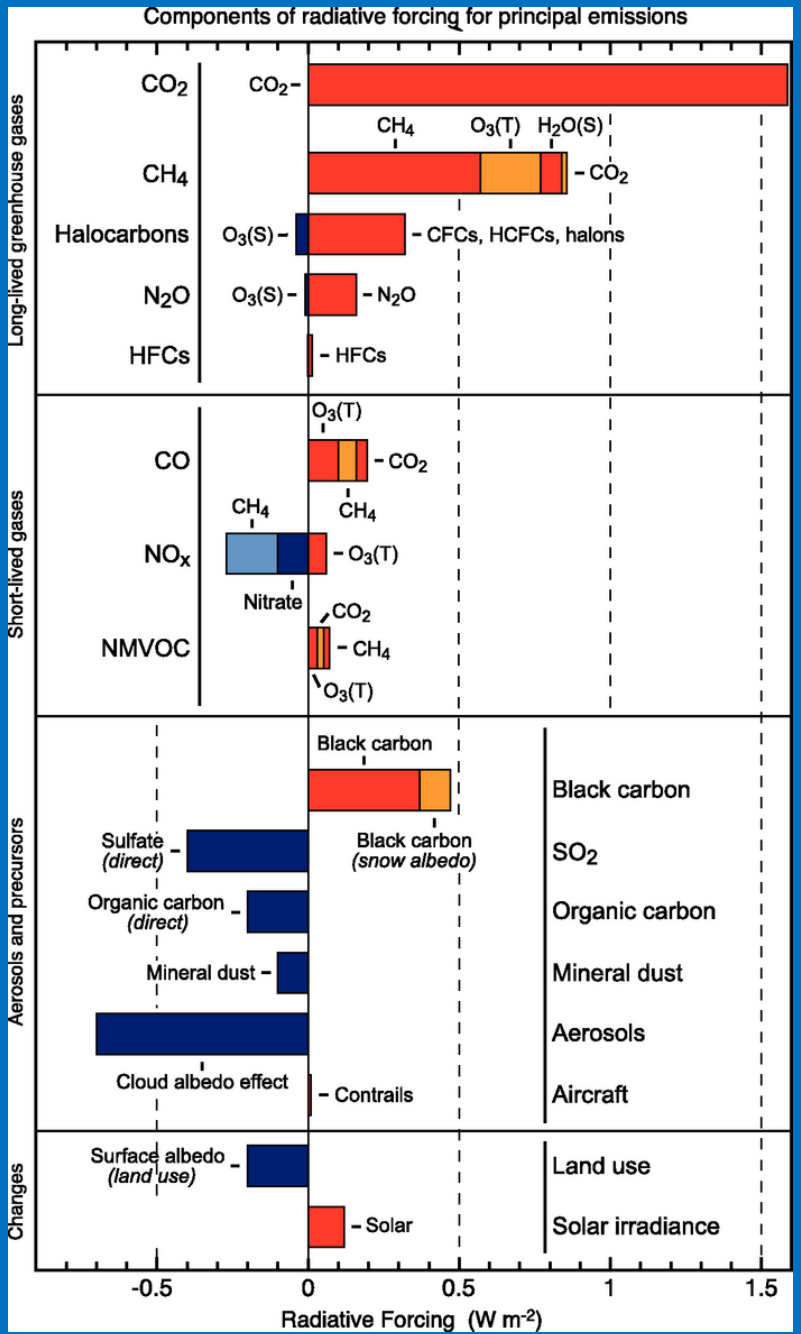
Fraction of population per continent in the Mediterranean



- ✓ *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 today more than half of the Mediterranean population leaving out of Europe (N. Africa and Middle-East)*


TOA
Surface
ΔQ
W/m²
0
3.0
GHG
Aerosol
-6.6
Aerosol
-17.9
Summer-time conditions

Climate Change & Air pollution



Long lived GREENHOUSE GASES
(direct emissions)
(CO2, CH4, CFCs, N2O)

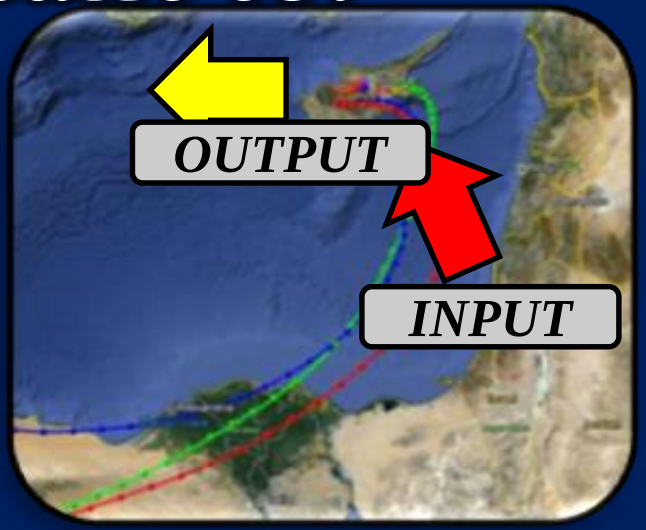
GREENHOUSE GASES
Emitted from short lived gases
(CO, NOx, NMVOC)

AEROSOLS warming = Black Carbon
(air + snow)
⇒ ***Black Carbon is the second greenhouse compound after CO2 !!!***

AEROSOLS cooling *(sulfate, organic, dust) & cloud interactions*

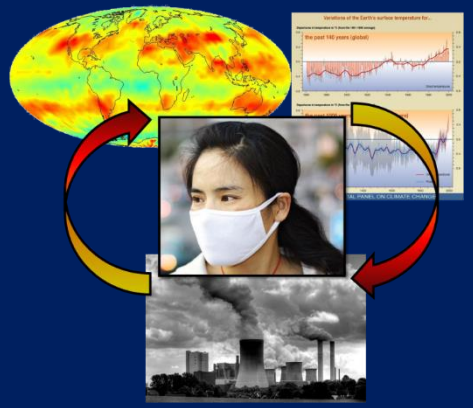
It is thus important to:

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

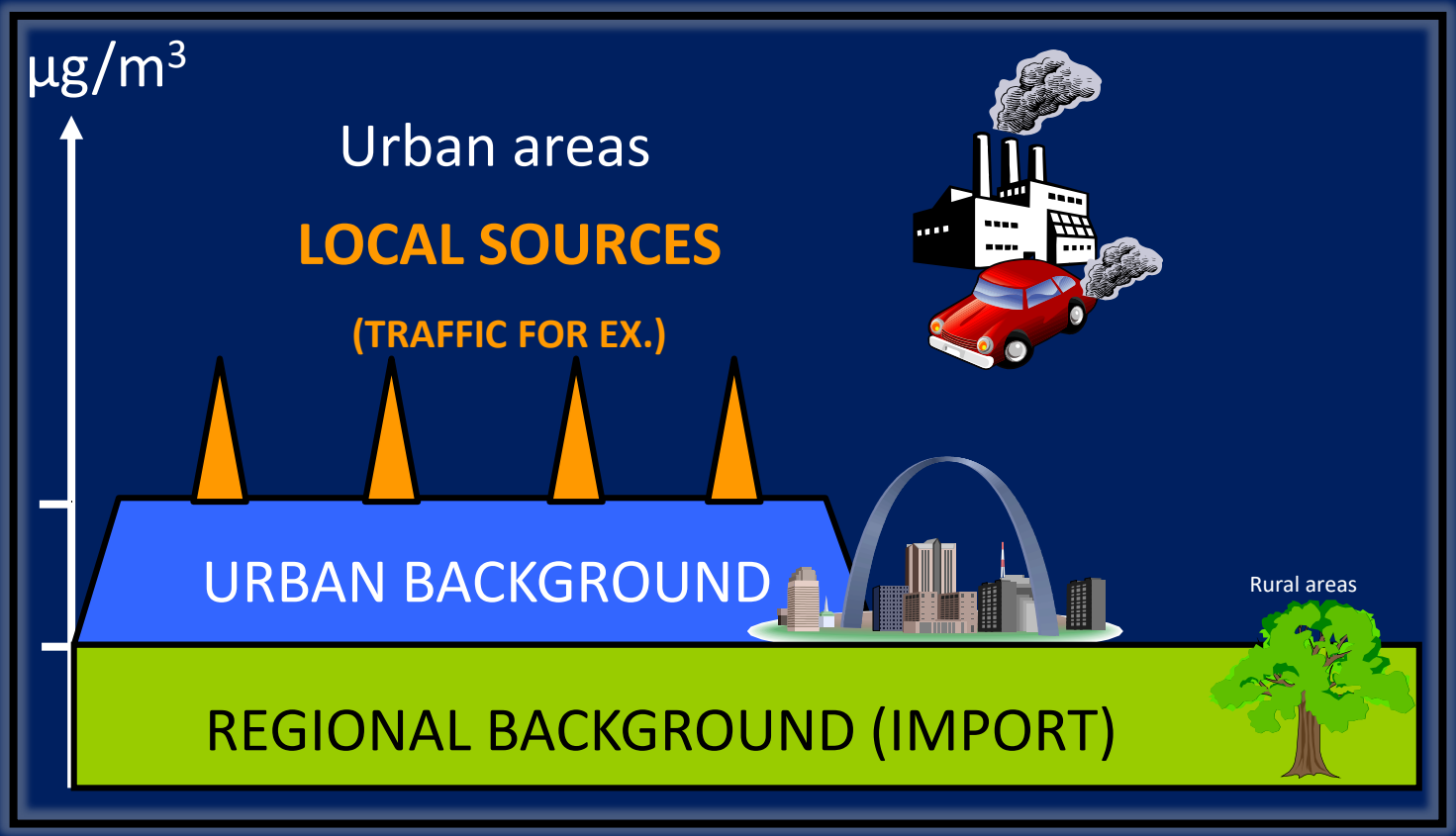


Composition and origin of pollutants (particles and gases)

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

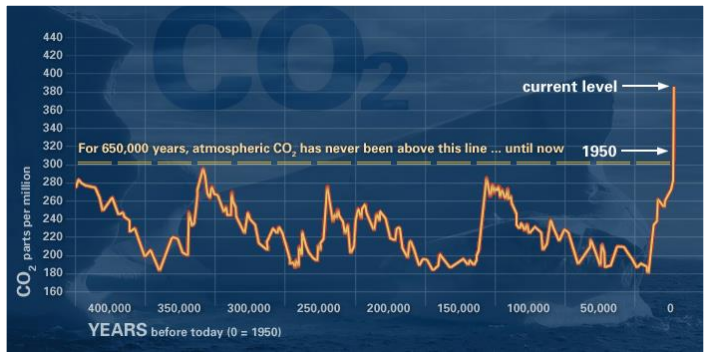


Information needed from all scales:
SPATIAL: Local → *Regional* → Global



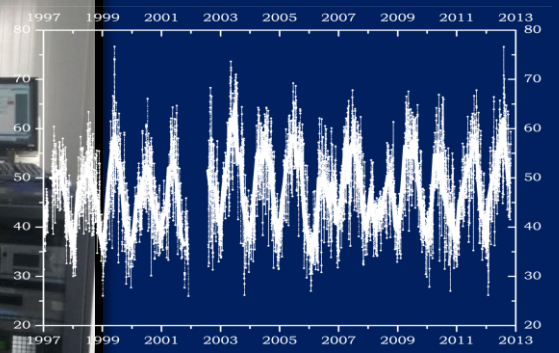
Need for simultaneous measurements in natural and urban locations.

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

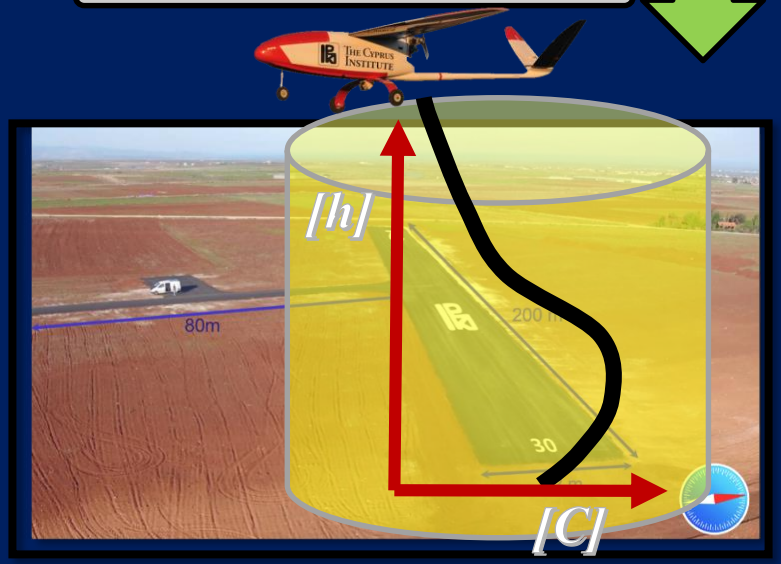
Monitoring stations



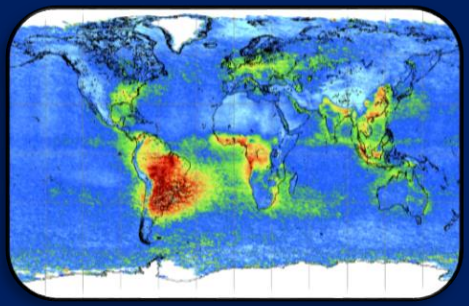
Observations

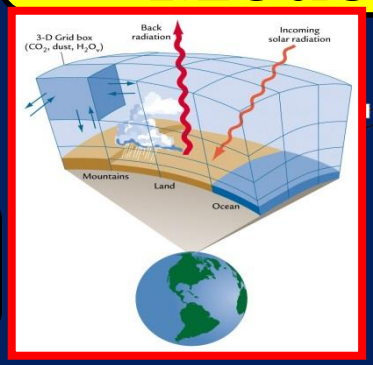
Numerical Models

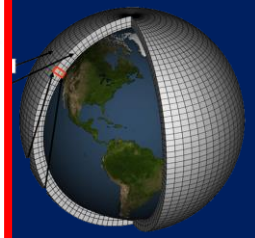
Airborne observations



Satellite observations

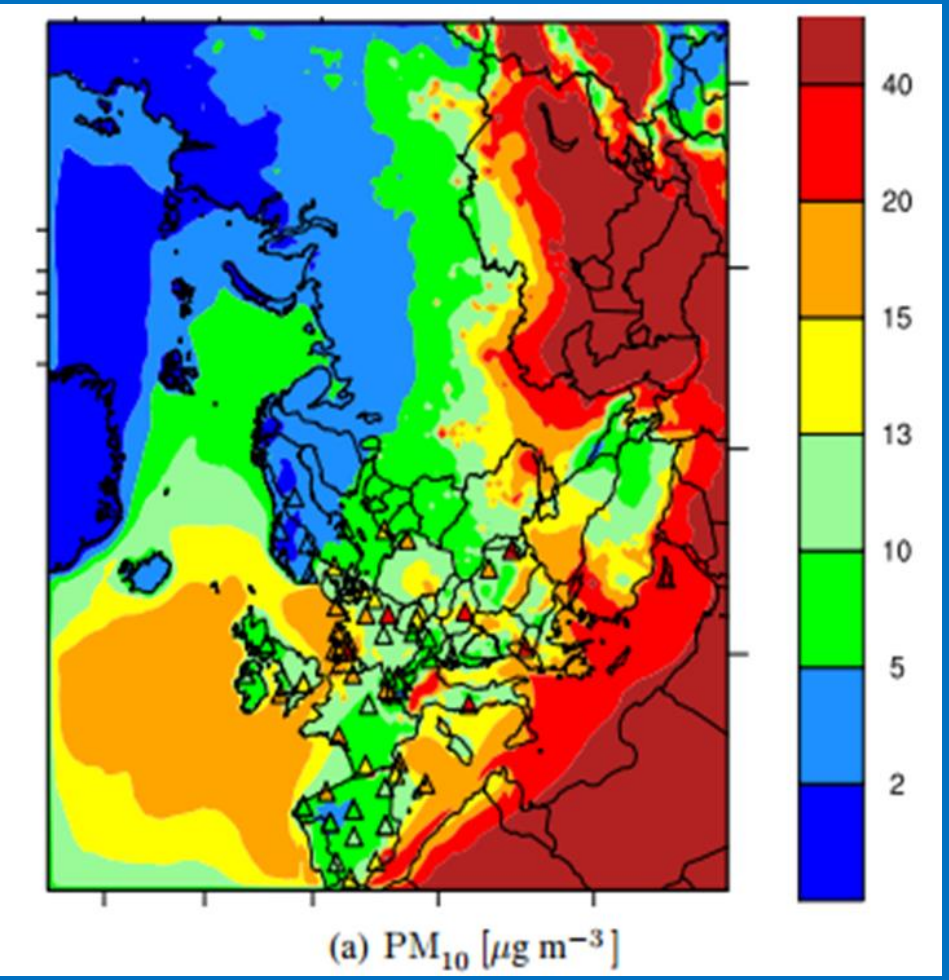






EU legislation on $PM_{2.5}$ and PM_{10}

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

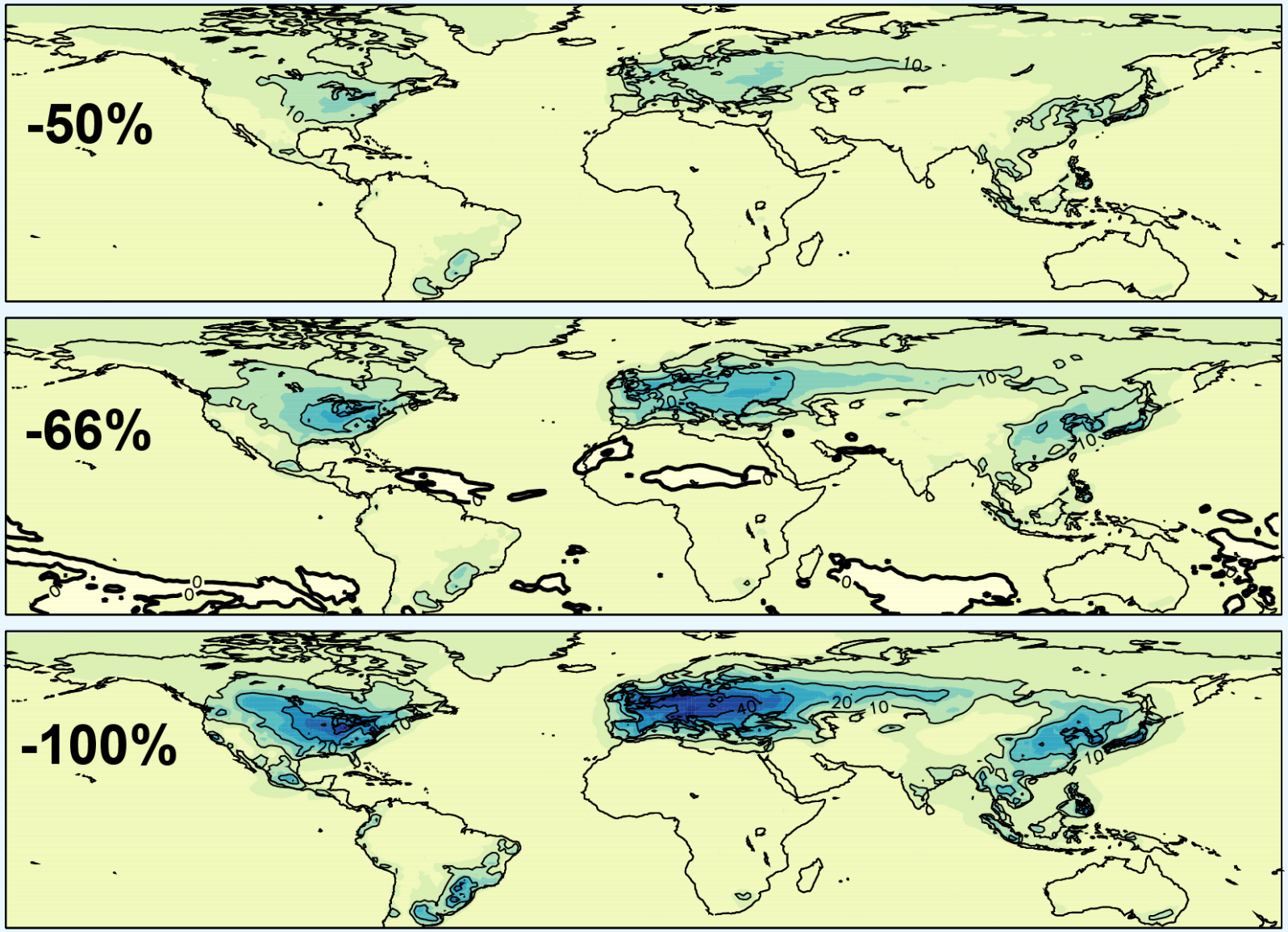


Annual EU limit PM_{10} = $40\mu g/m^3$

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

http://emep.int/publ/reports/2015/EMEP_Status_Report_1_2015.pdf

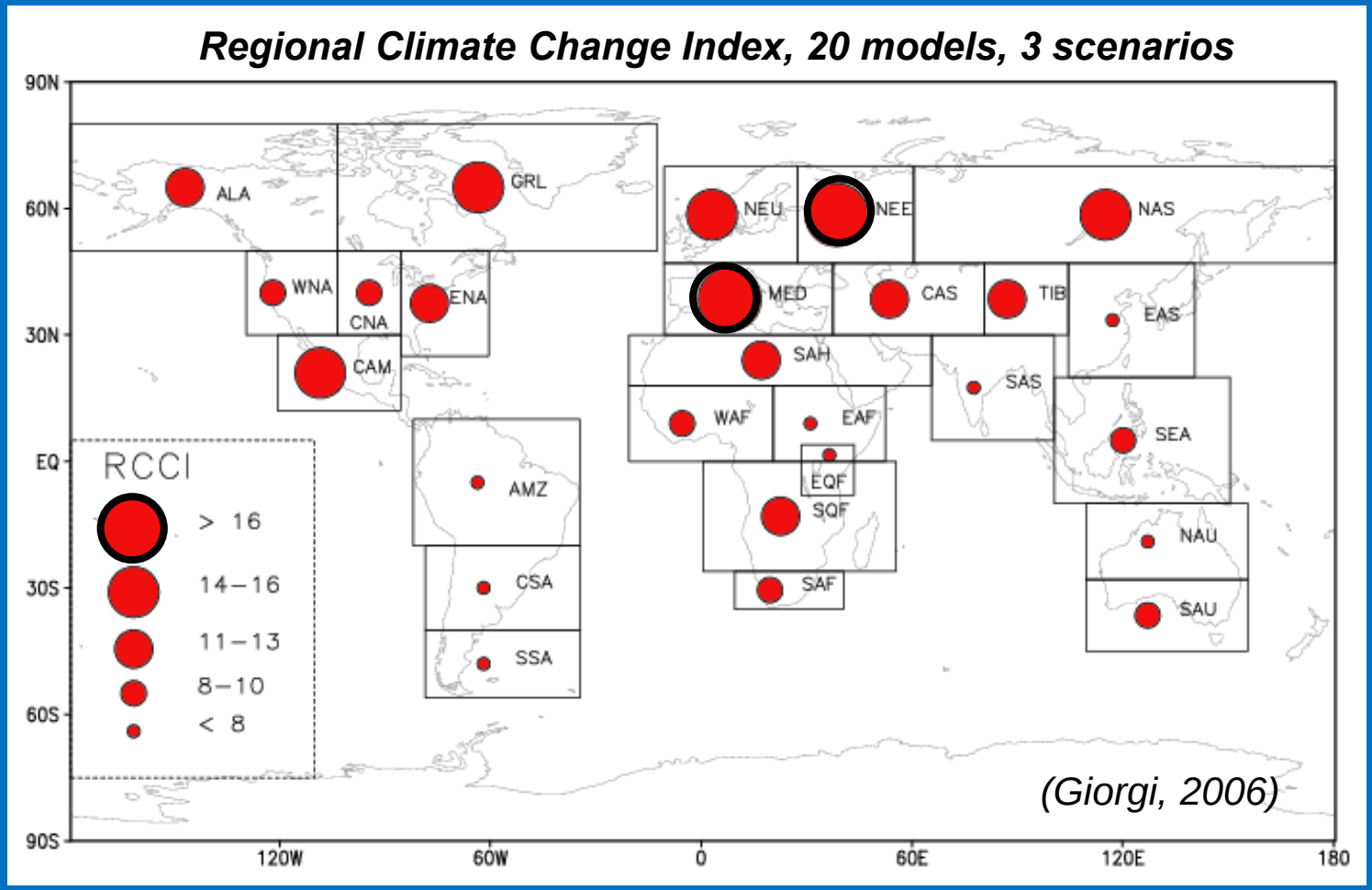
Reducing agricultural emissions (NH_3)



Air pollution & Climate Change in the Mediterranean

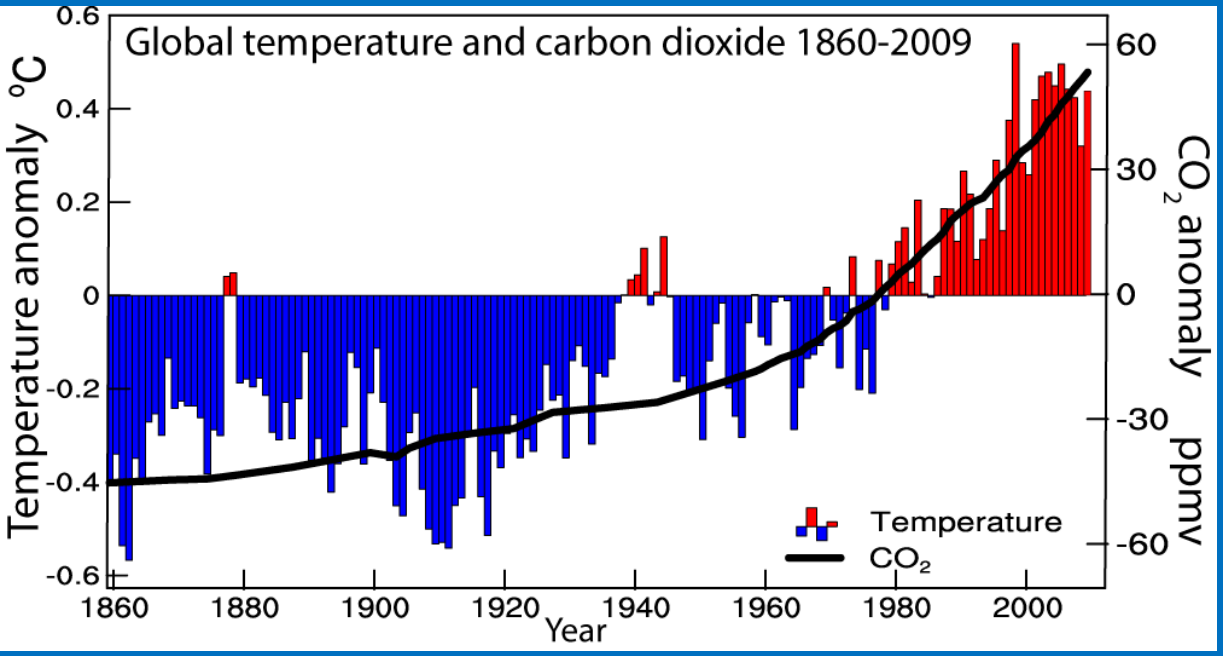
The Mediterranean: *A major climate Hot Spot region*

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



➢ ***Climate is especially responsive to global change in Mediterranean***

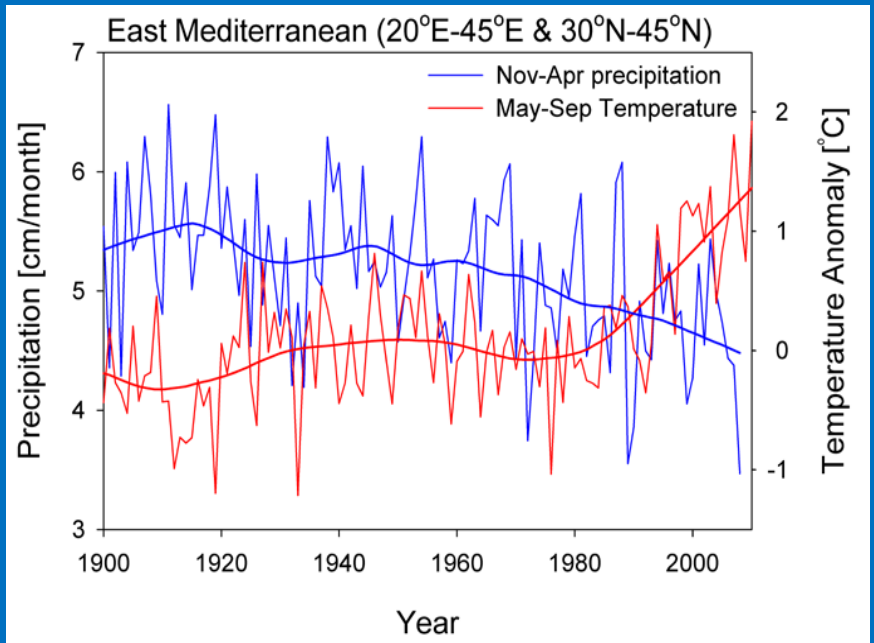
Climate Change & Air pollution in the Mediterranean



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

(Baseline period: 1961-1990)
Source: ttp://www2.cgd.ucar.edu/

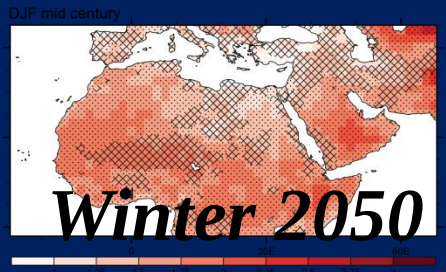
<u>Climate Change between 1980-2010</u>
World : = +0.5 degree C
Eastern Mediterranean = +1.5 degree C !!!

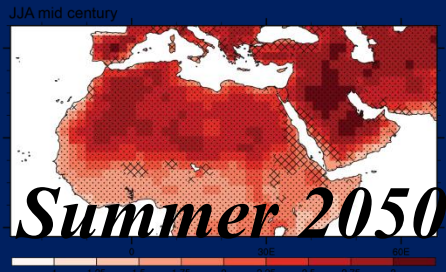


***<u>High Impact region</u>**: trends in temperature and precipitation go in different directions*
(The World Bank, 2012)

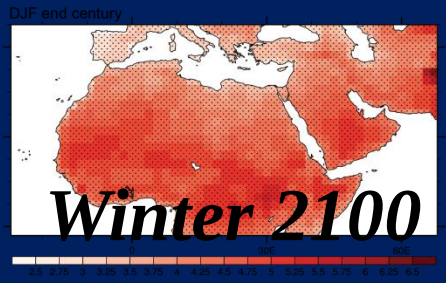
Regional climate models at the Cyprus Institute

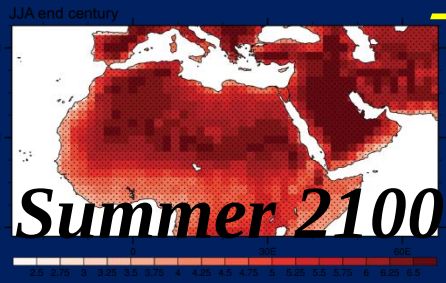
Coupled Model Inter-comparison Project Phase 5 – CMIP5:



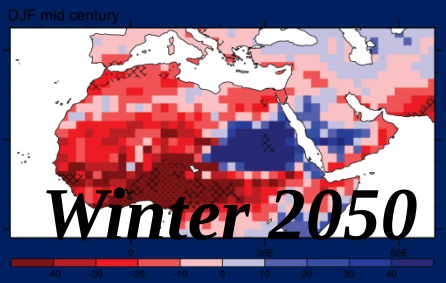


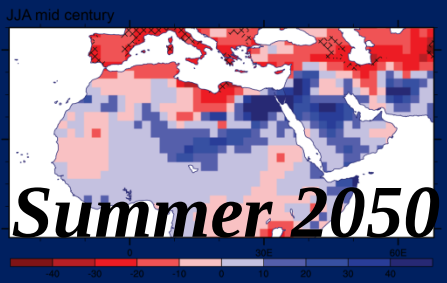
Temperature projections



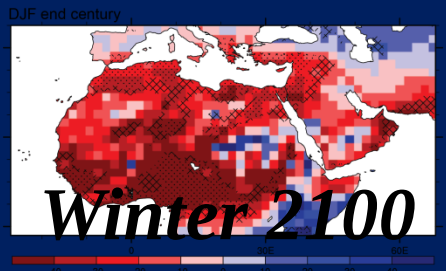


⇒ **Summer will become warmer**

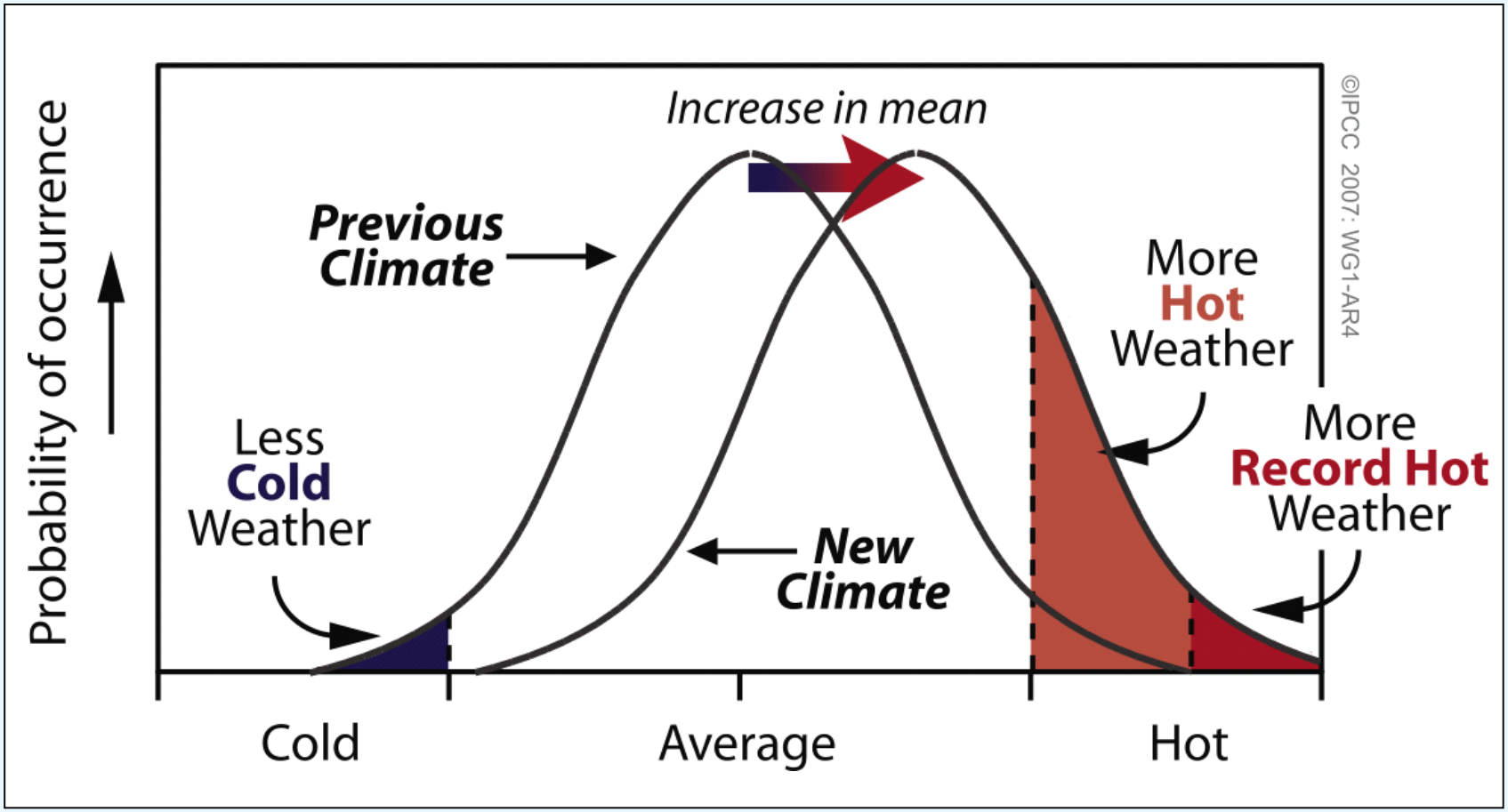




Precipitation projections



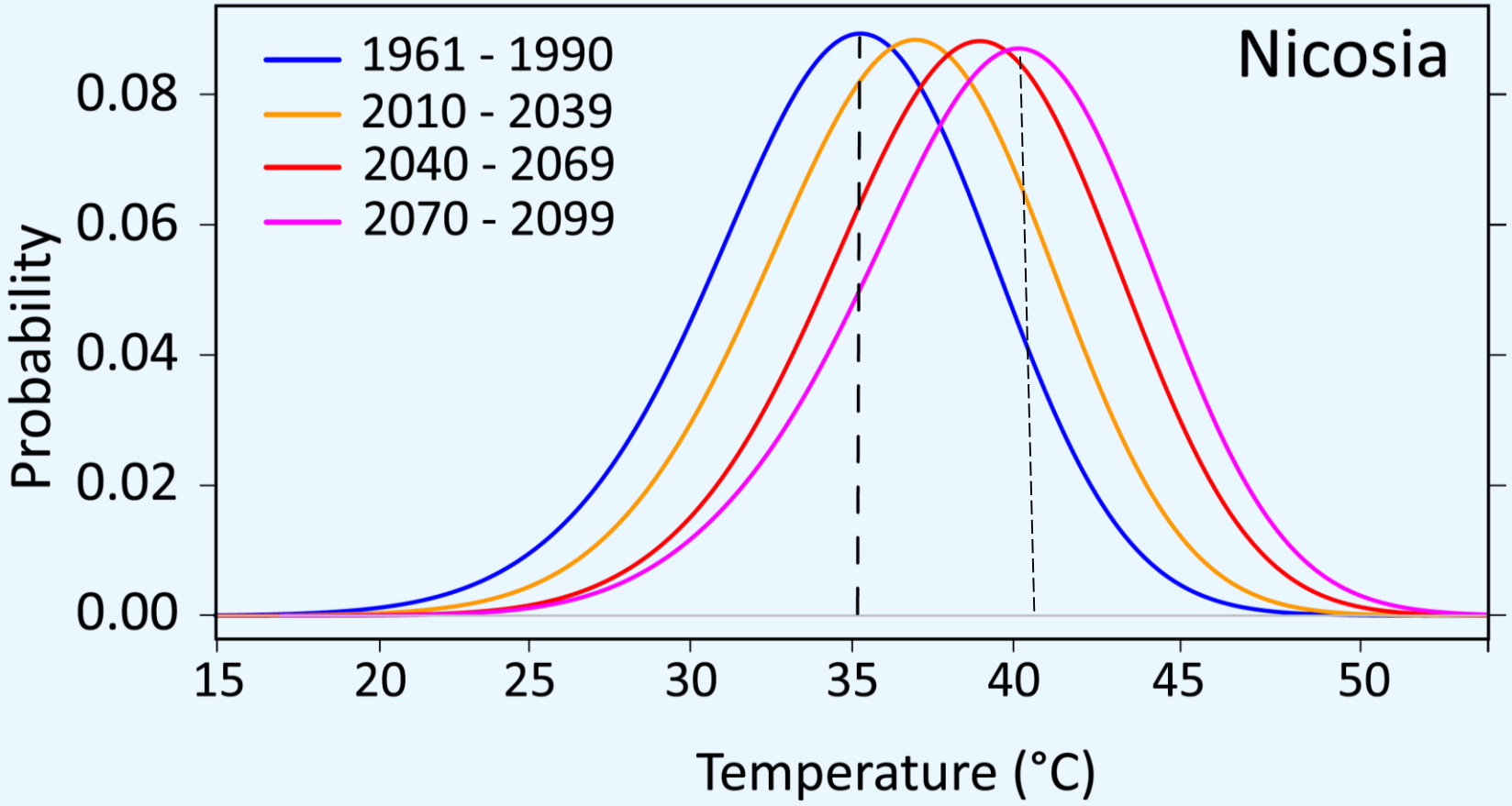
⇒ **Winter will become dryer**



Heat waves are major weather-related cause of premature mortality

Relationship between temperature extremes and cerebrovasular disease (stroke) and ischemic heart disease (heart attack)

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

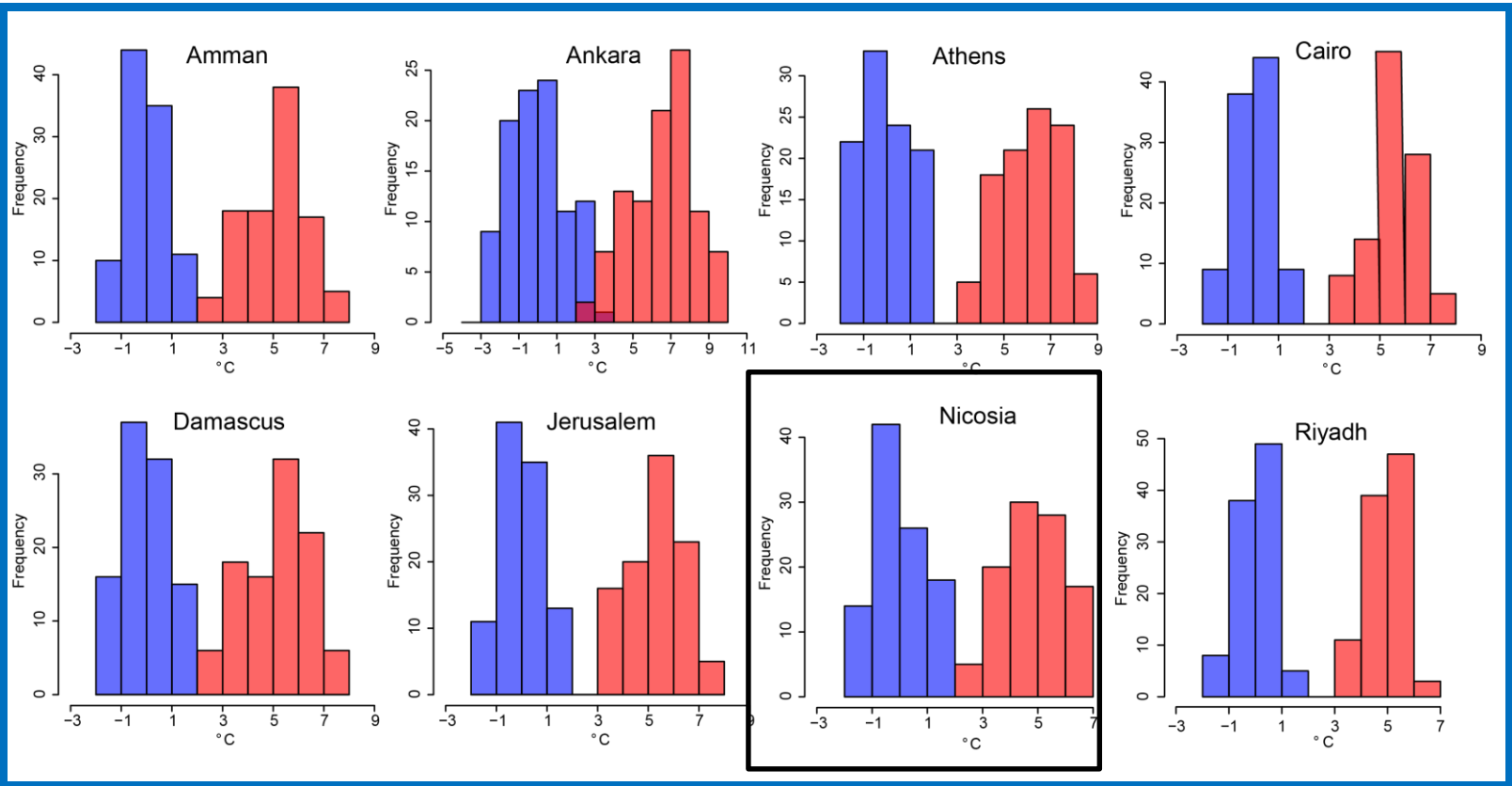


Regional climate models at the Cyprus Institute

Frequencies of summer (JJA) maximum temperature anomalies (%) –HEAT WAVES-

Blue is for the reference period 1961-1990 (centered around 0°C)

Red is for 2070-2099



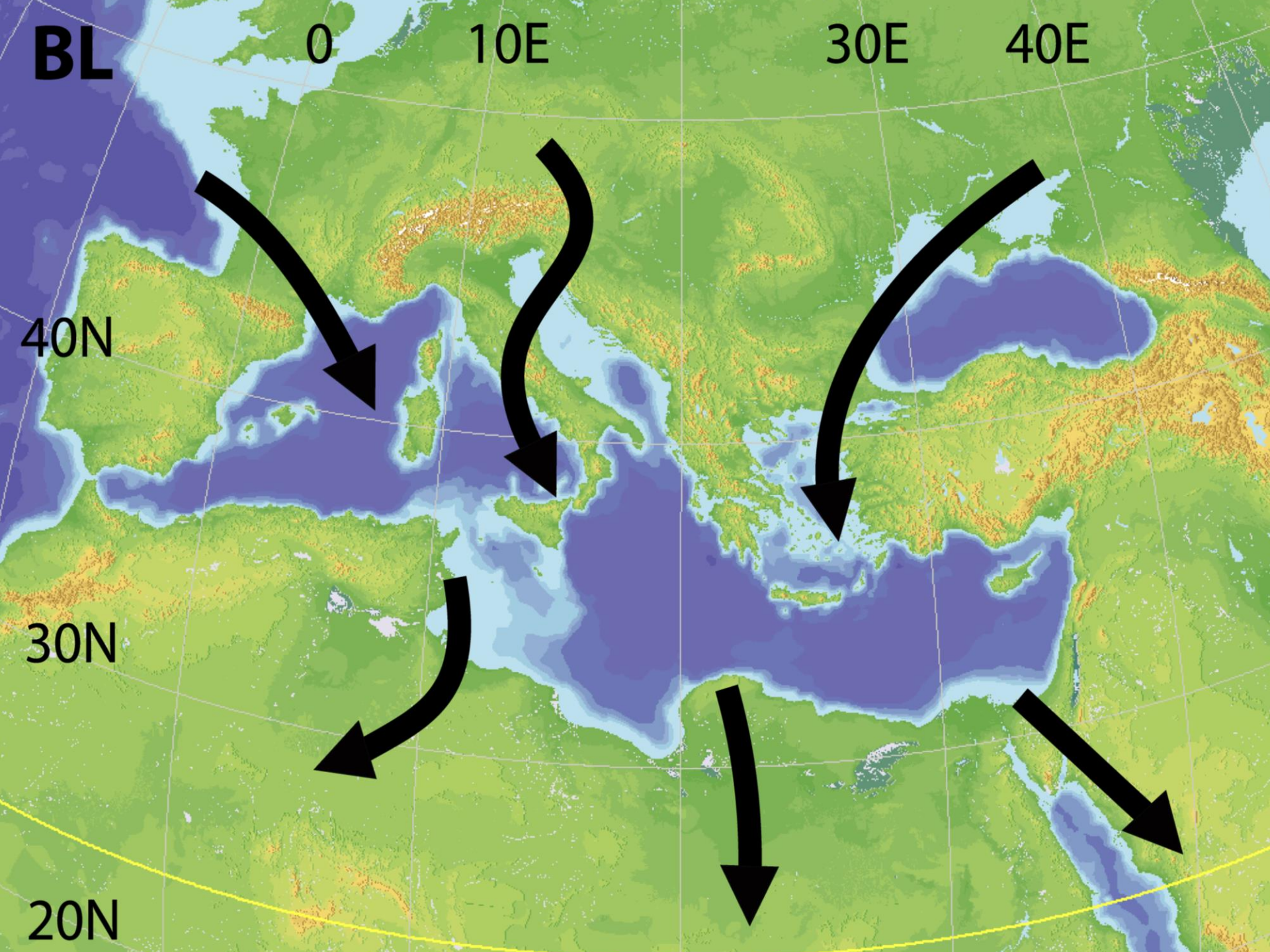
Heat waves

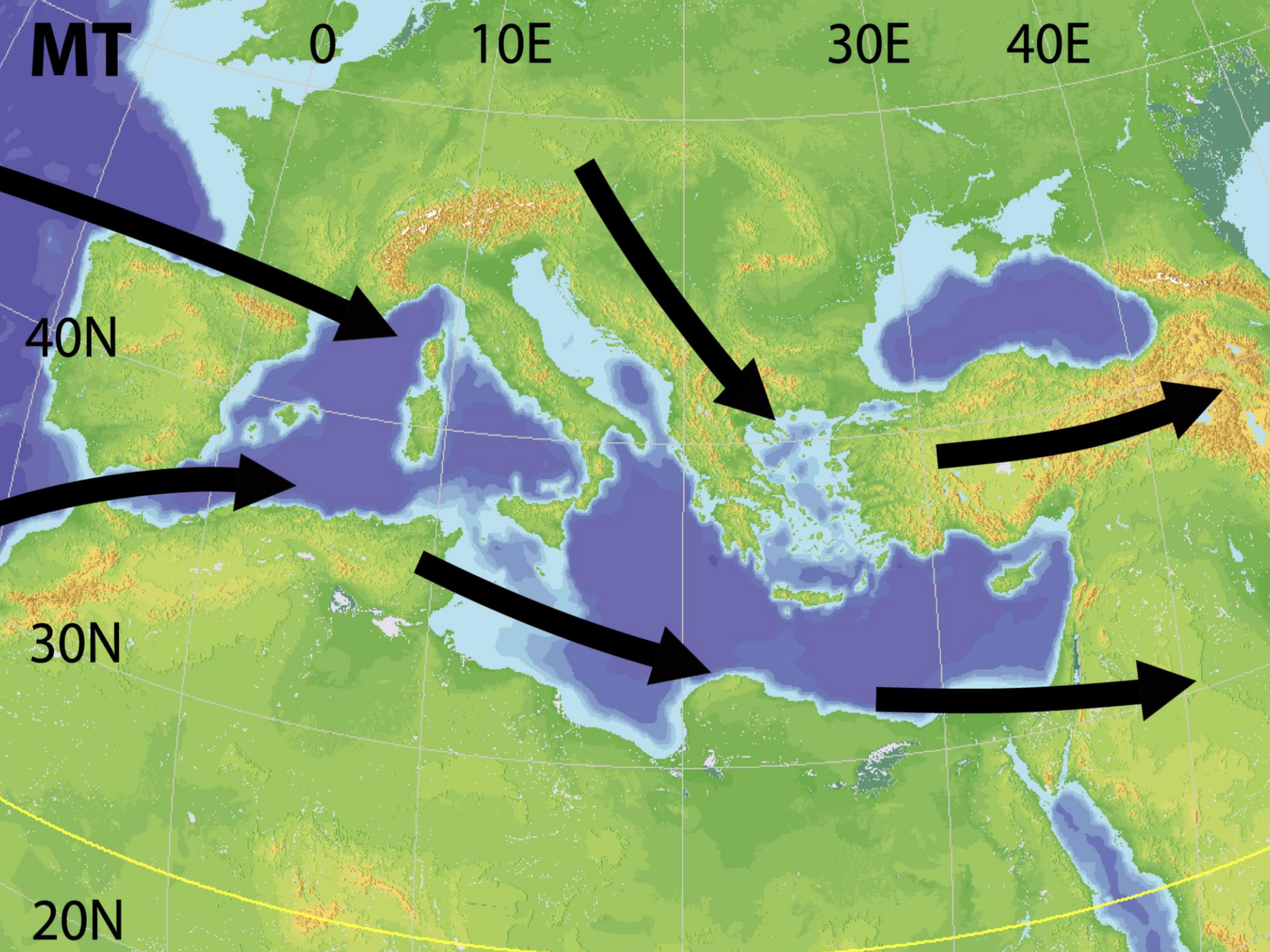
⇒More frequent & warmer

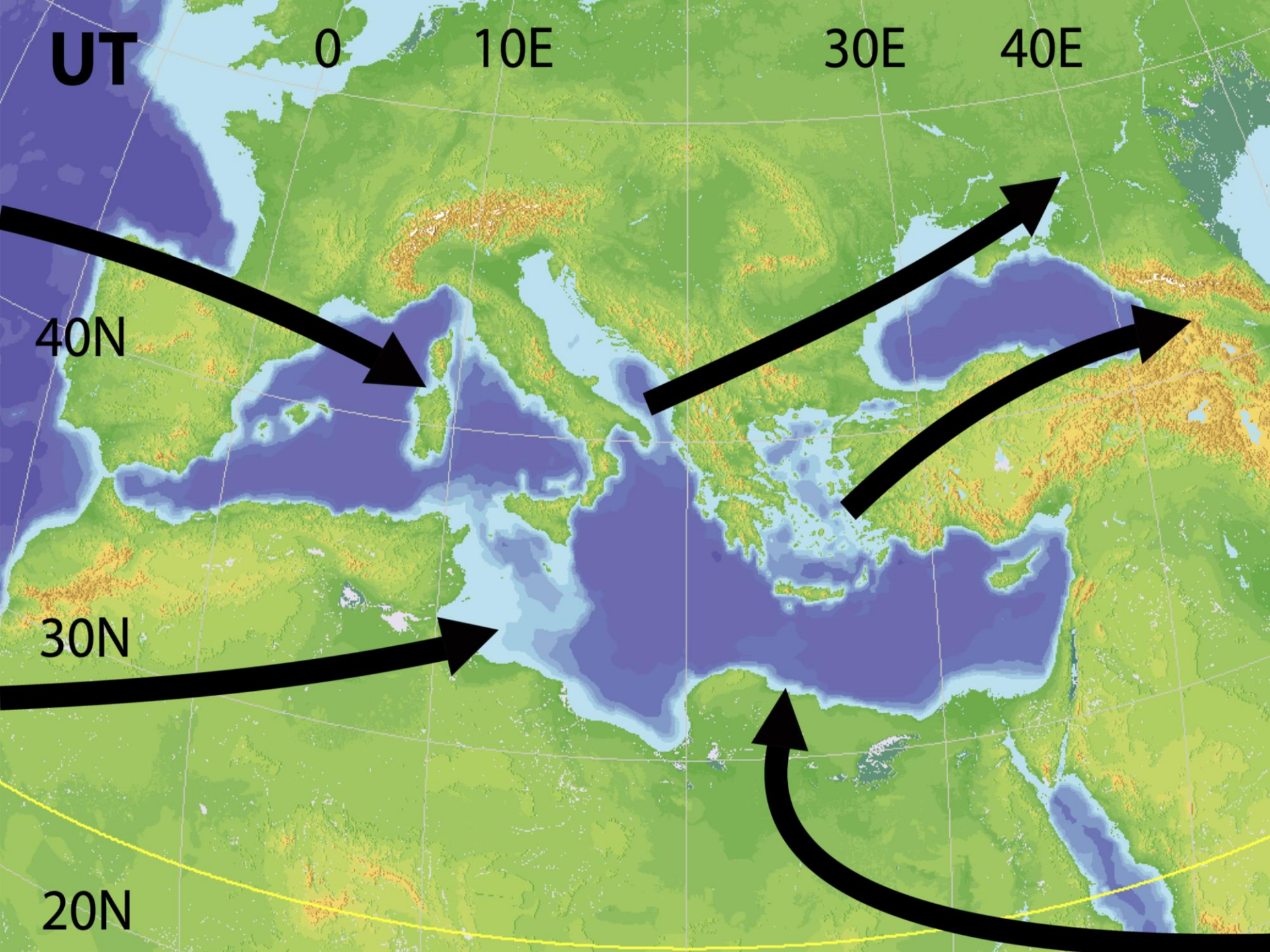
PRECIS downscaling simulations of the A1B scenario

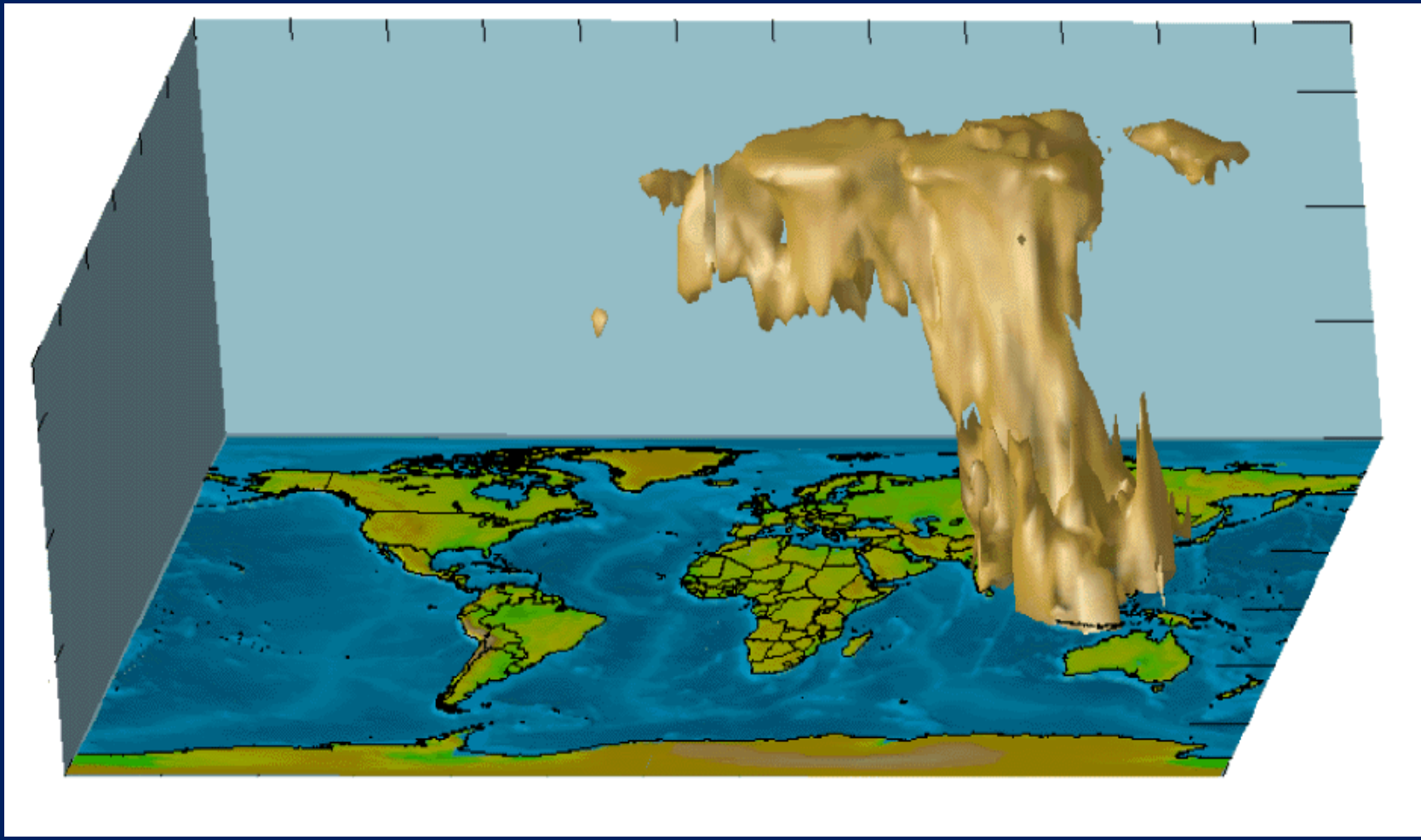
Mediterranean Intensive Oxidant Study (MINOS)
Crete, summer 2001

Finokalia (UoC)

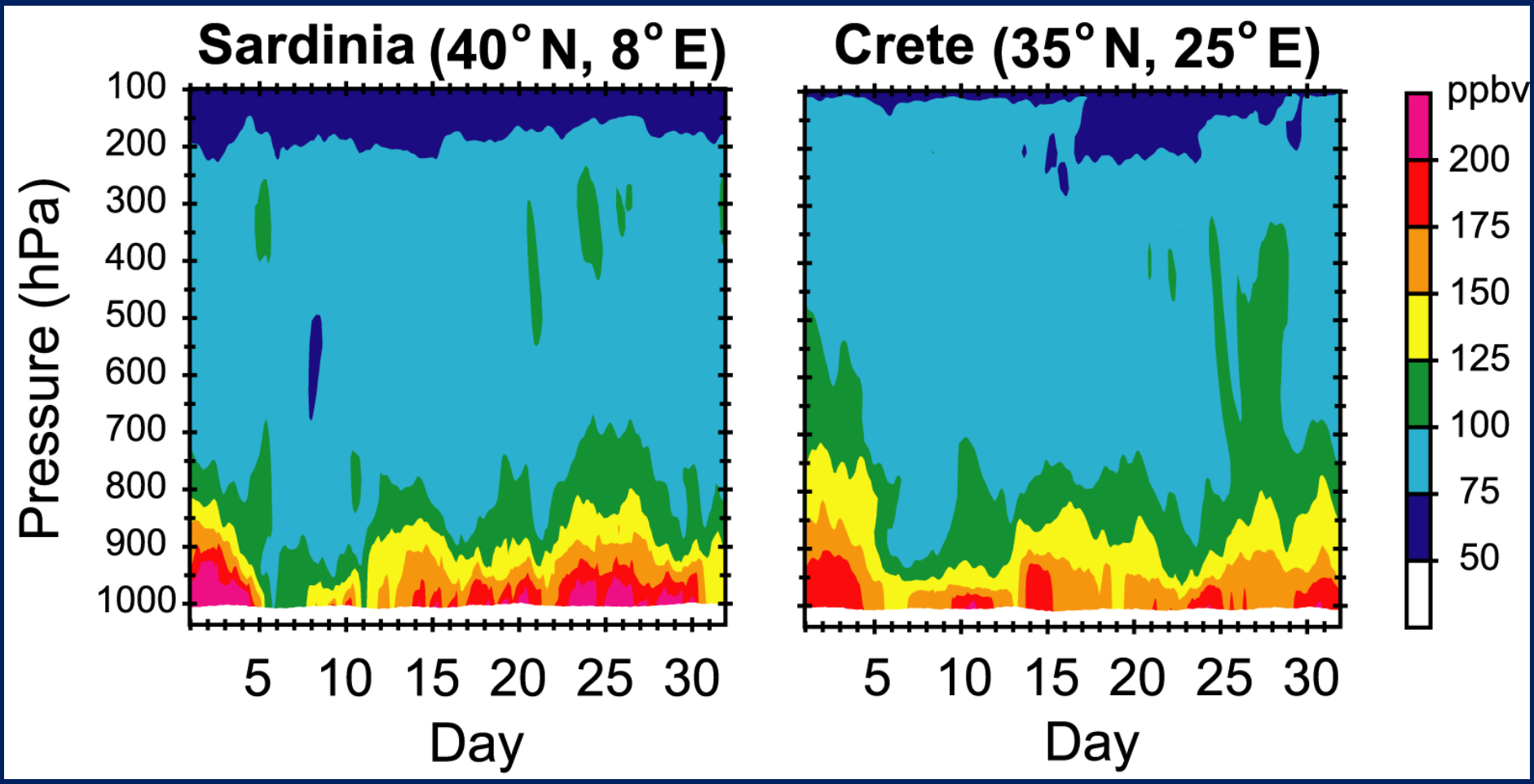

BL
0
10E
30E
40E
40N
30N
20N

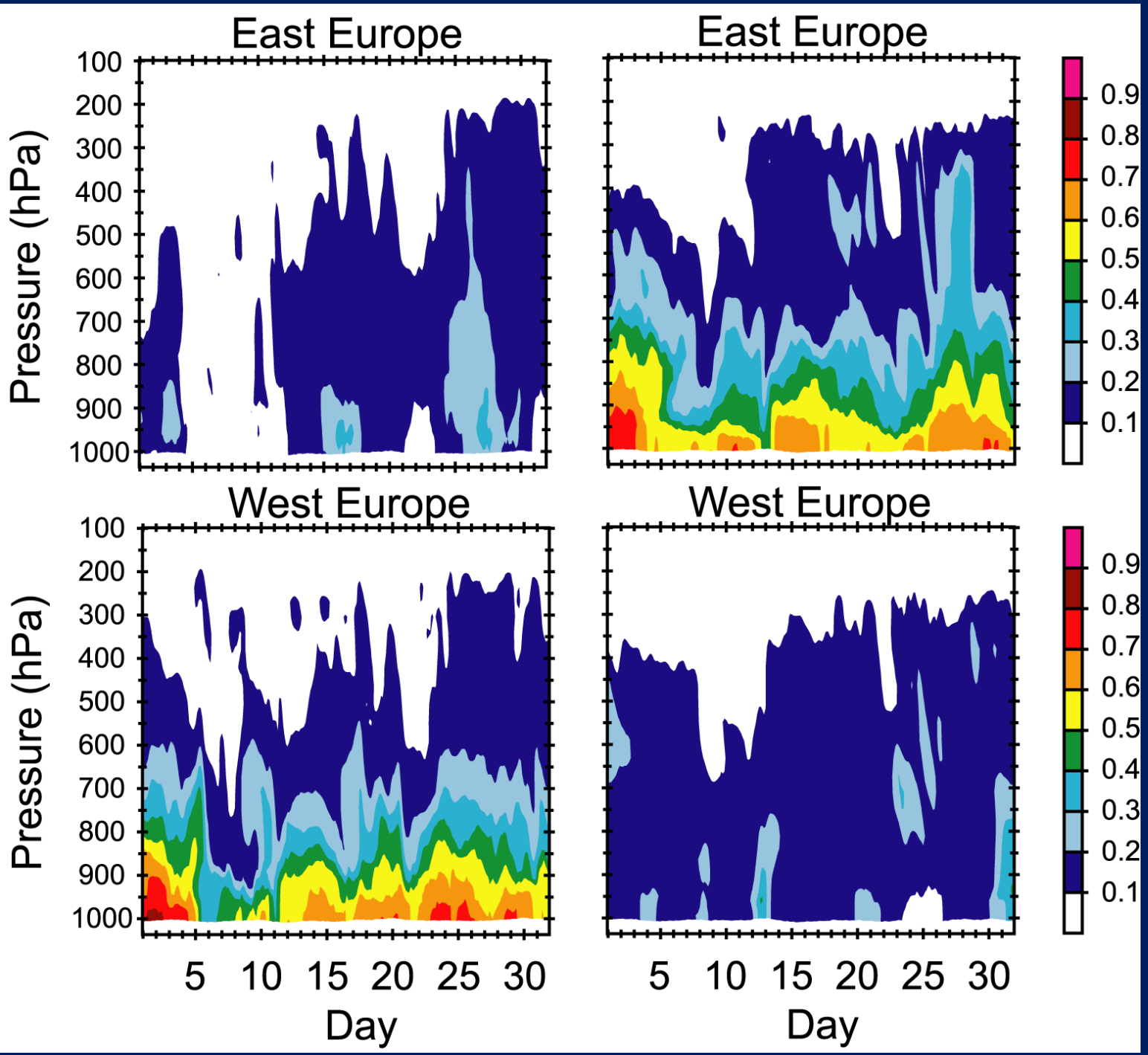

MT
0
10E
30E
40E
40N
30N
20N

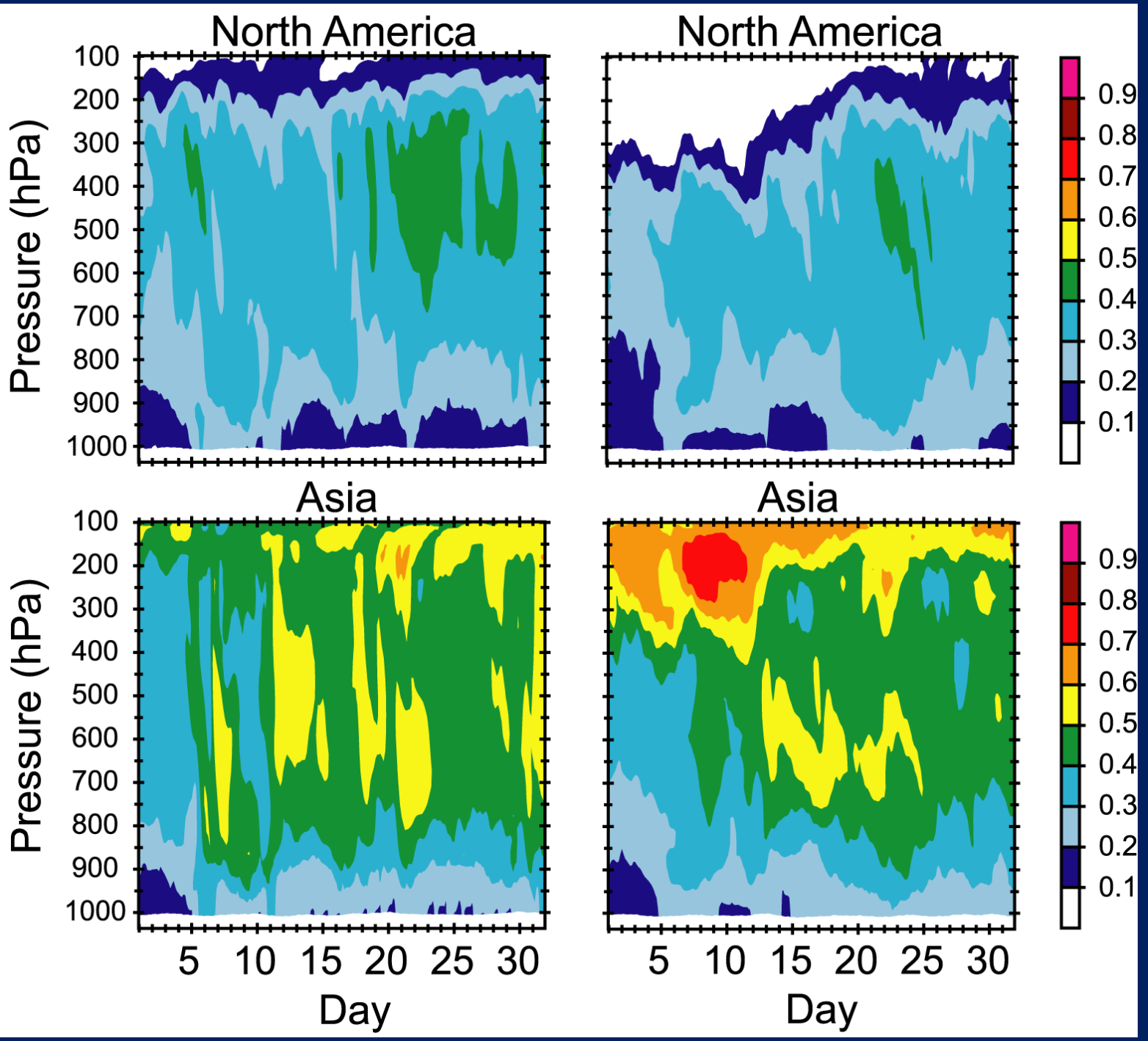

UT
0
10E
30E
40E
40N
30N
20N



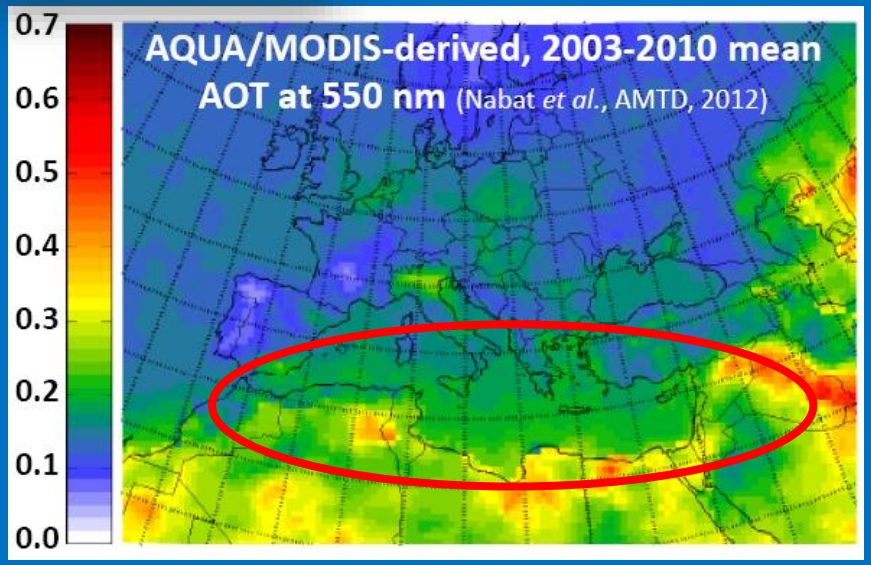
Model calculation of pollution transport from South Asia (Lawrence et al., 2002).
Thunderstorms in the summer monsoon carry pollution to the Mediterranean at altitudes above 8-10 km (the upper troposphere).


Sardinia (40° N, 8° E)
Crete (35° N, 25° E)
Pressure (hPa)
100
200
300
400
500
600
700
800
900
1000
5
10
15
20
25
30
Day
ppbv
200
175
150
125
100
75
50


East Europe
East Europe
West Europe
West Europe
Pressure (hPa)
Pressure (hPa)
100
200
300
400
500
600
700
800
900
1000
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
5
10
15
20
25
30
Day
Day

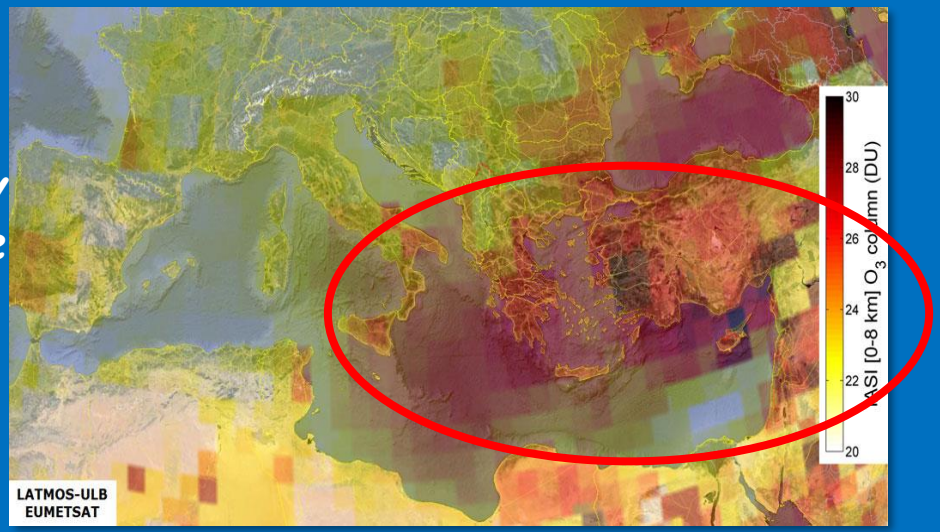

North America
North America
Asia
Asia
Pressure (hPa)
Pressure (hPa)
100
200
300
400
500
600
700
800
900
1000
5
10
15
20
25
30
Day
Day
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

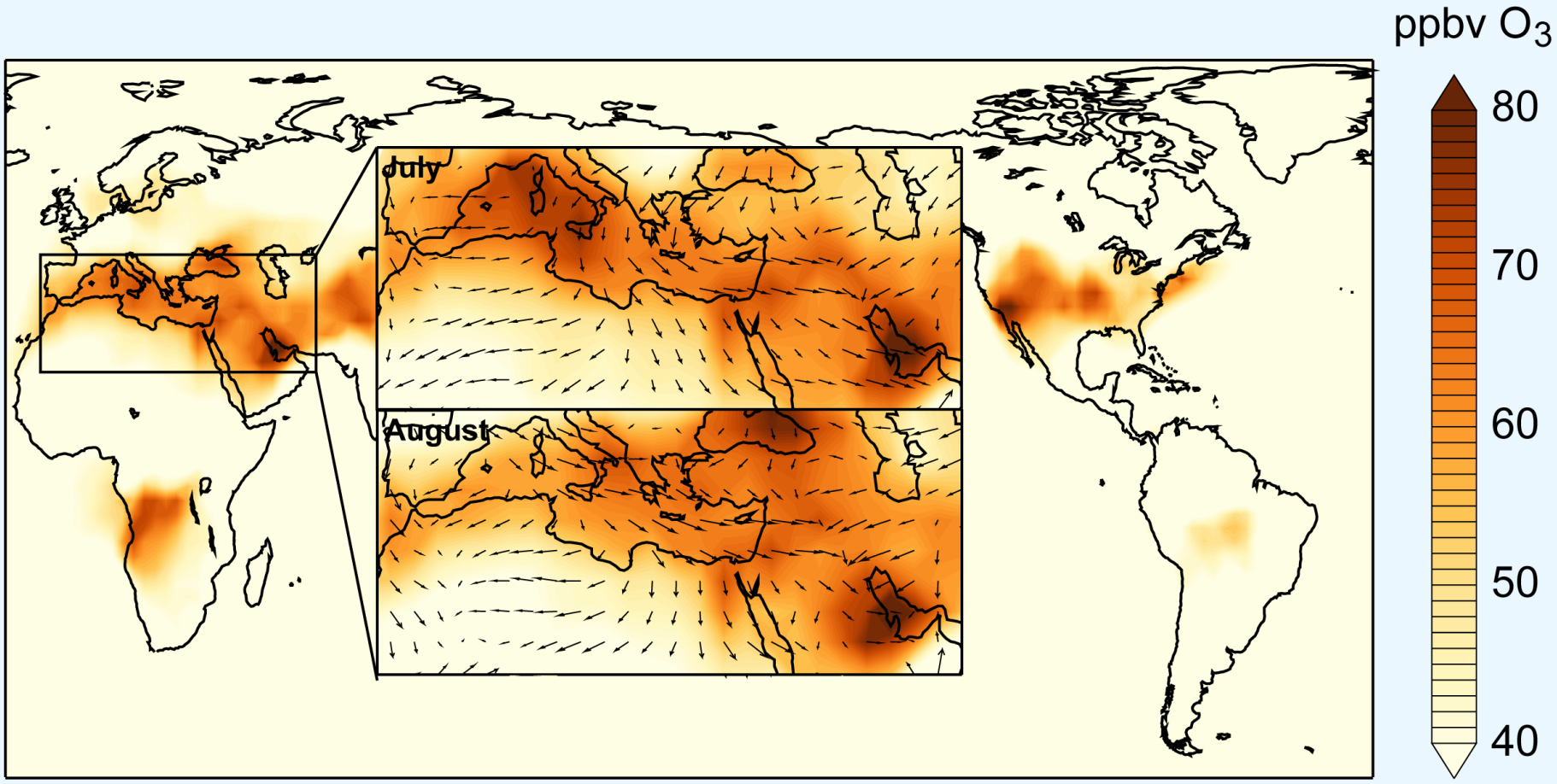
Air Pollution in the E. Mediterranean: As observed from satellites



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

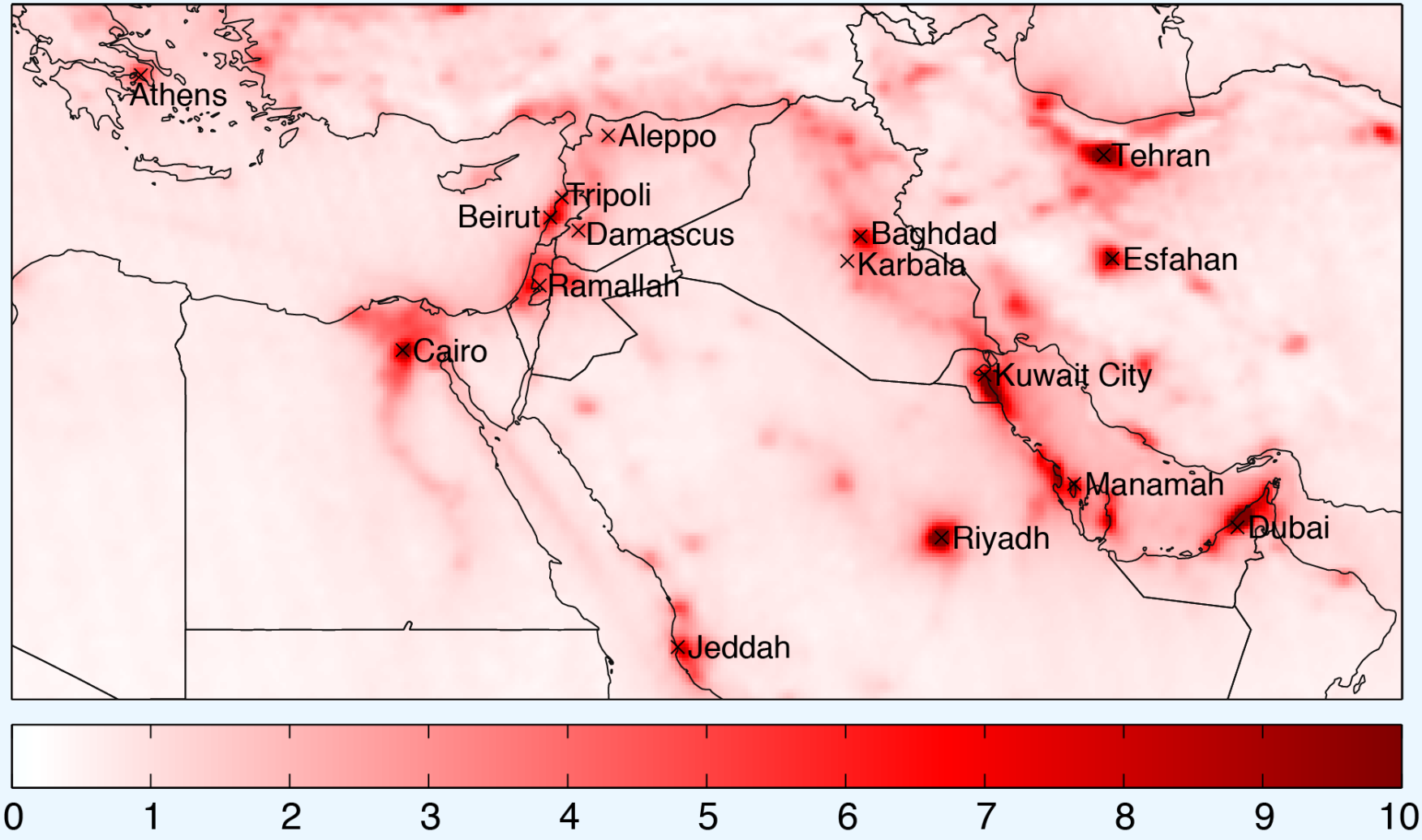




Ozone at the Earth‘s surface in summer (June – August)

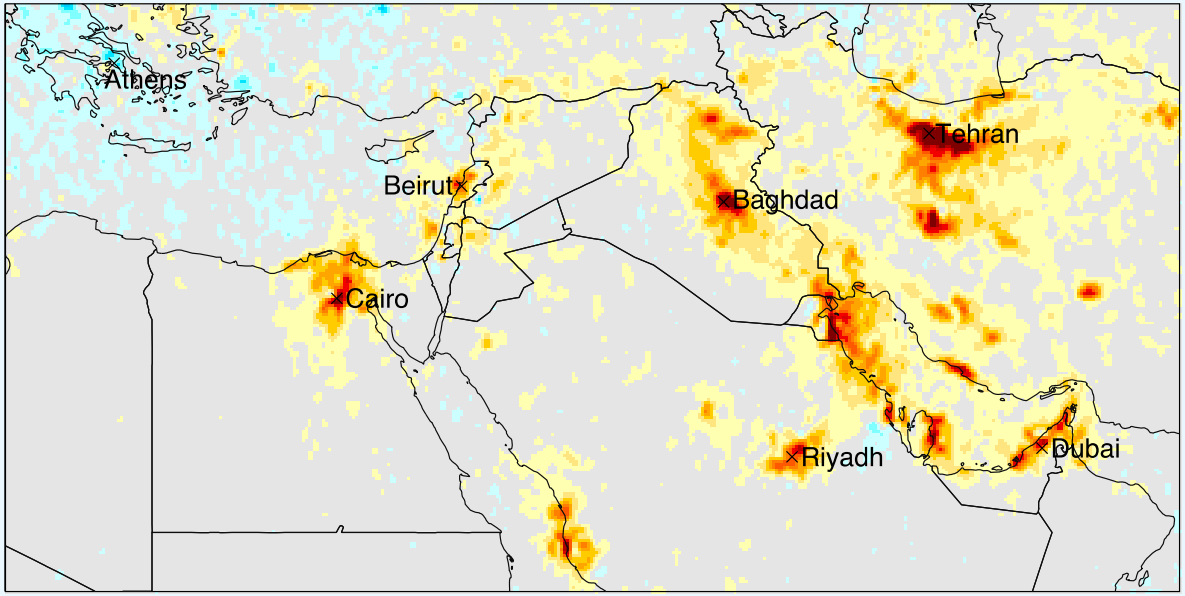
Abrupt trend changes in atmospheric NO_2 observed from space

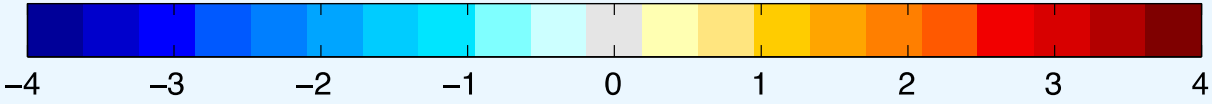
NO_2 column densities in 10^{15} molecules/cm^2 during period 2005 – 2014



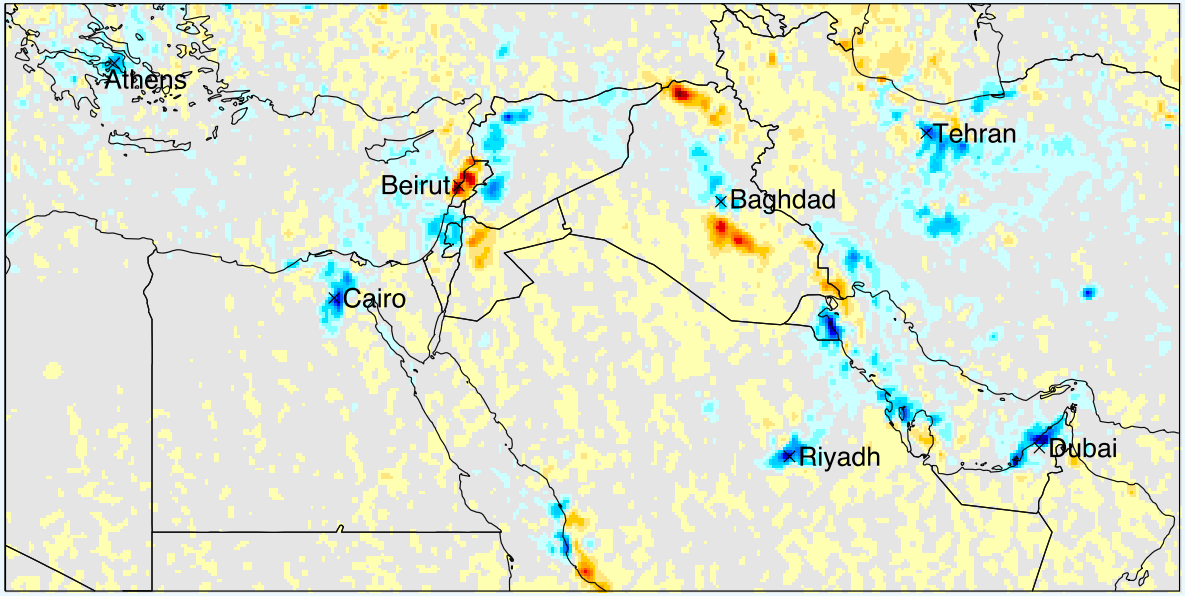
NO_2 changes in 10^{15} molecules/cm^2

2005 to 2010

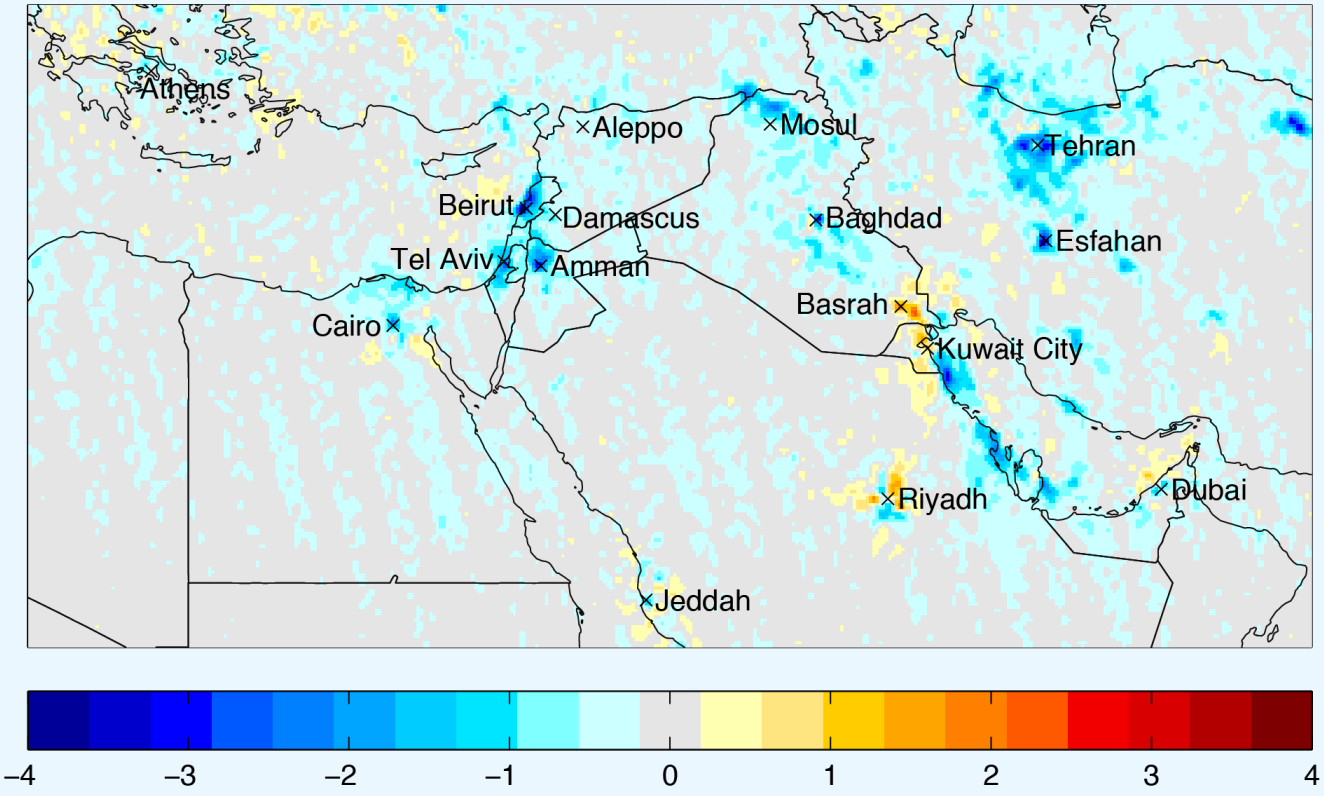




2010 to 2014



2014 to 2015

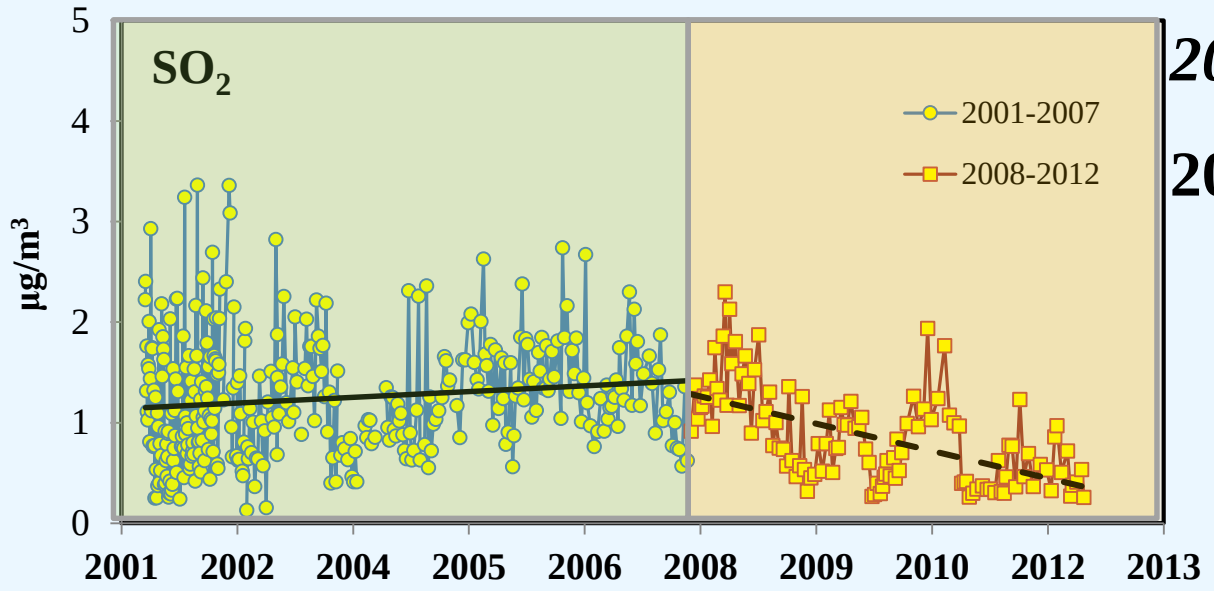


NO_2 changes in 10^{15} molecules/cm^2

TRENDS in the W. Mediterranen and E. Mediterranean from measurements of particulate and gaseous precurors

The Mediterrannean Atmospheric Network

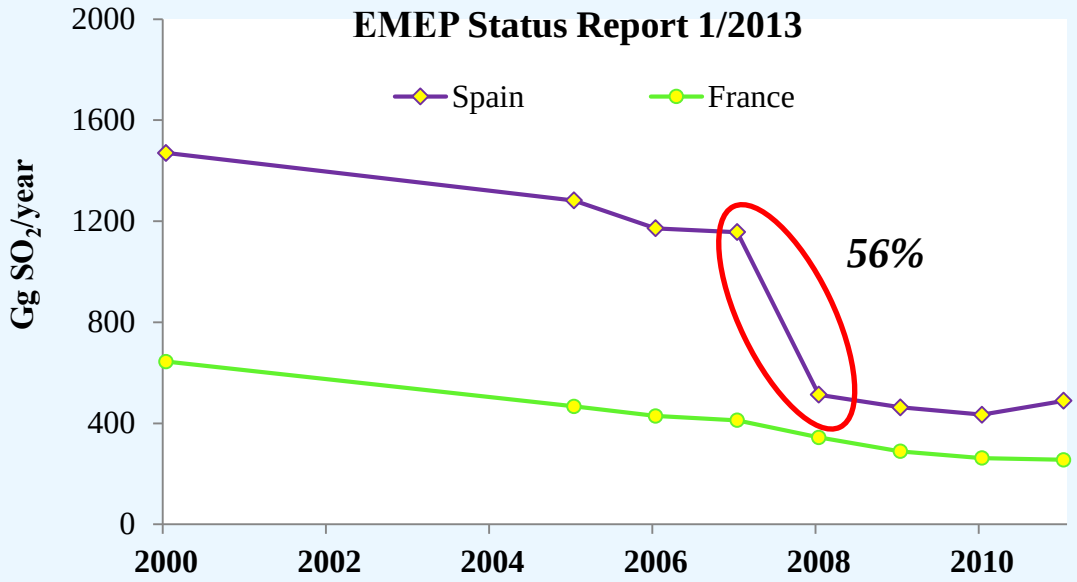
CORSICA: *Trends of the Main Gases and Aerosols*



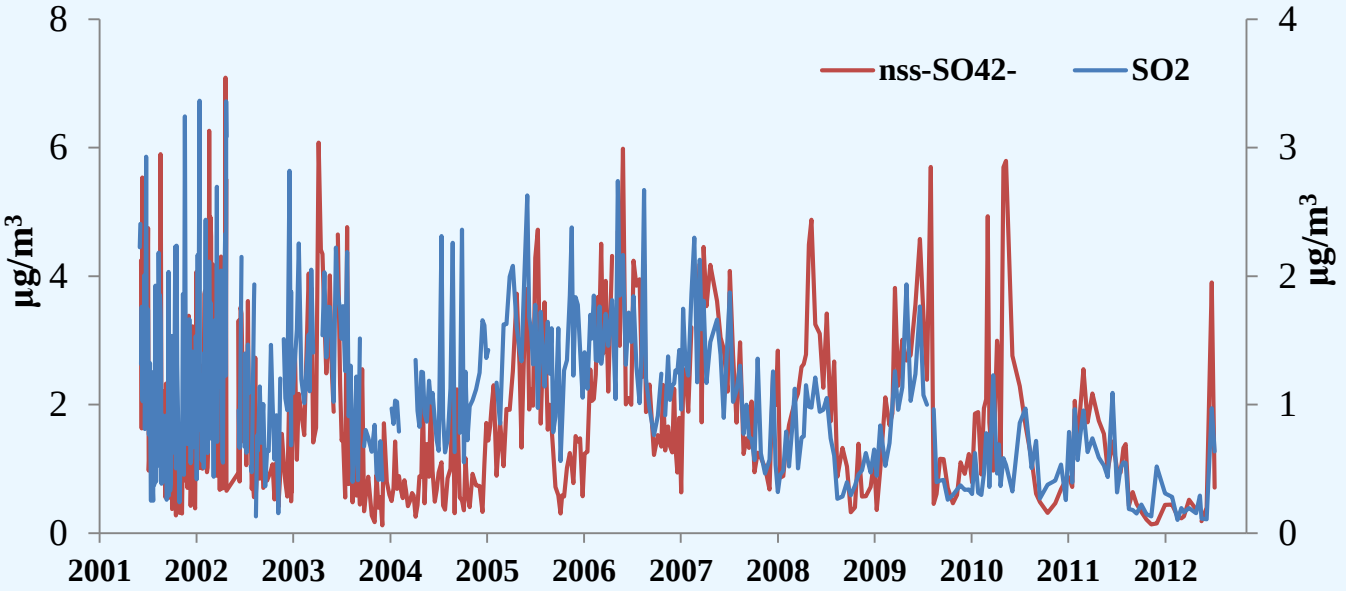
***2001-7* : 1,3 ± 0,2 µg/m³**

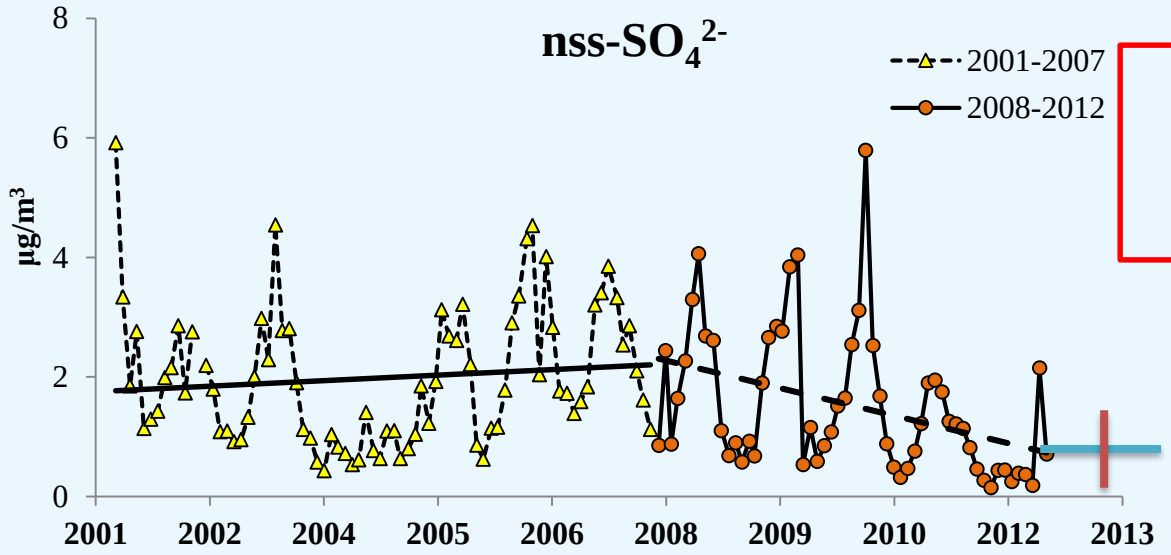
2008-12 : 0,56 ± 0,2 µg/m³

decreasing trend (56 %)



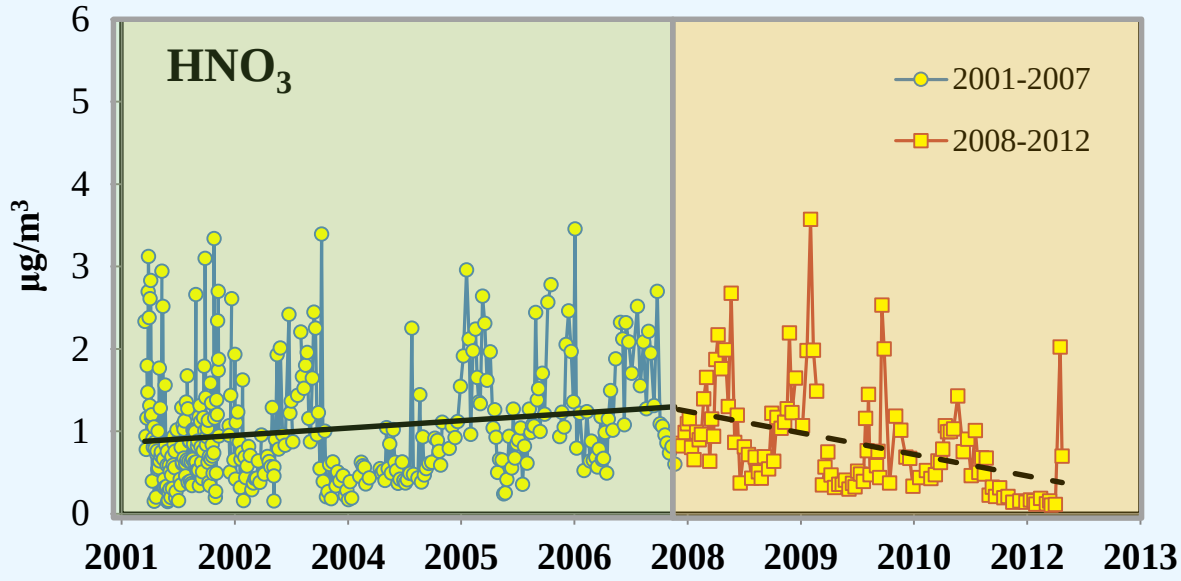
CORSICA: *Trends of the Main Gases and Aerosols*



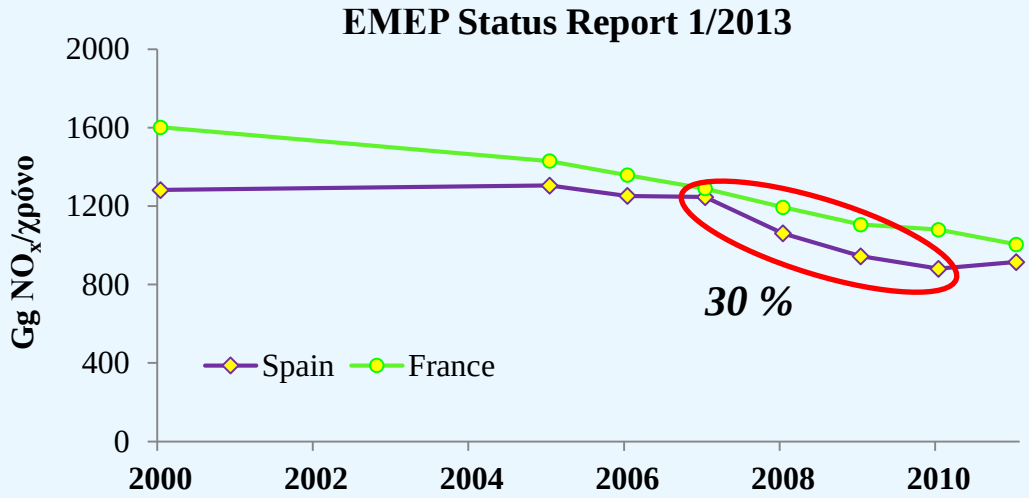


decreasing trend (30%)

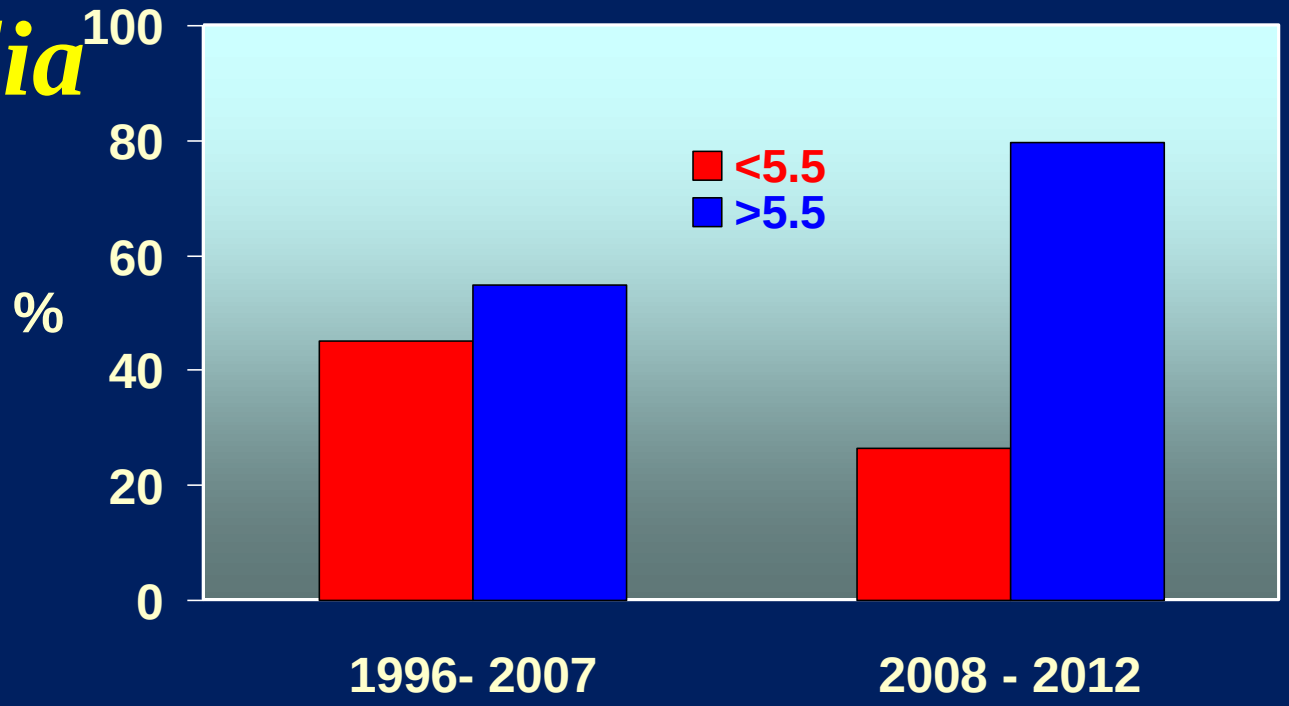
CORSICA: *Trends of the Main Gases and Aerosols*

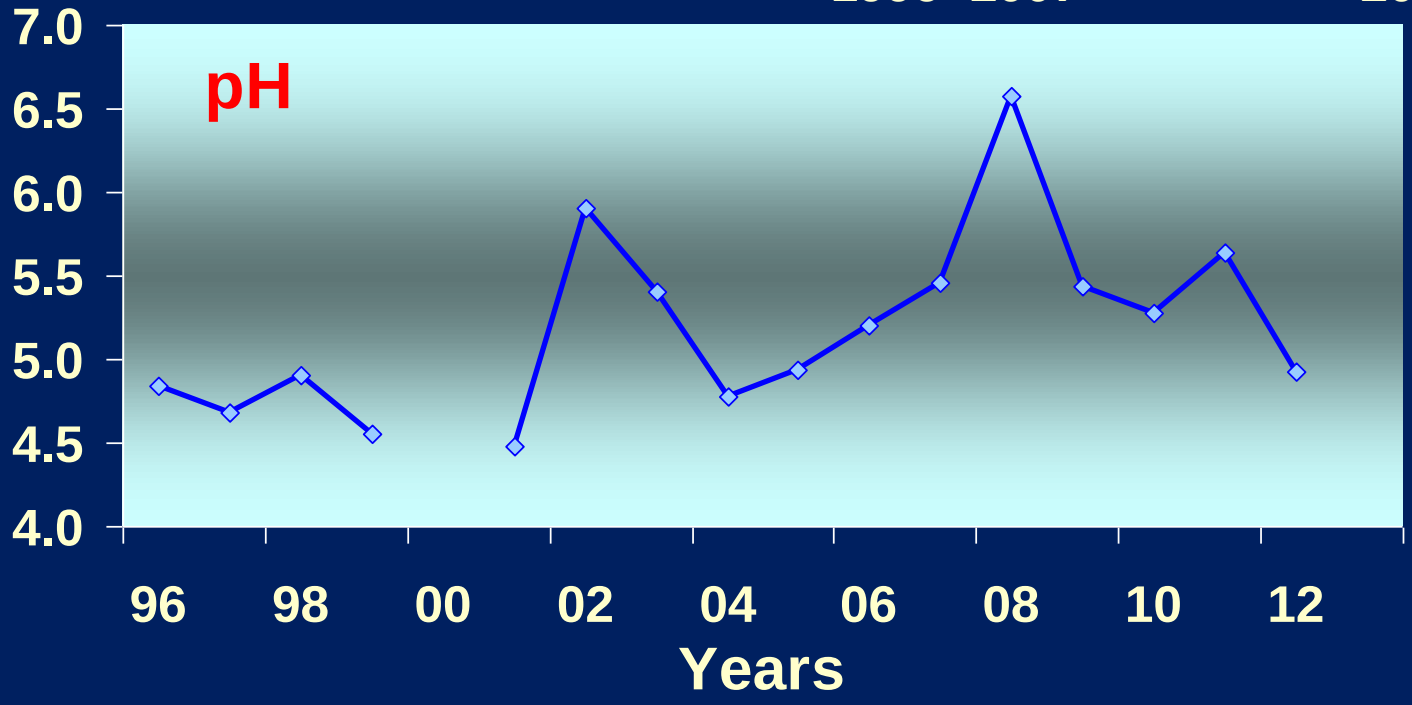


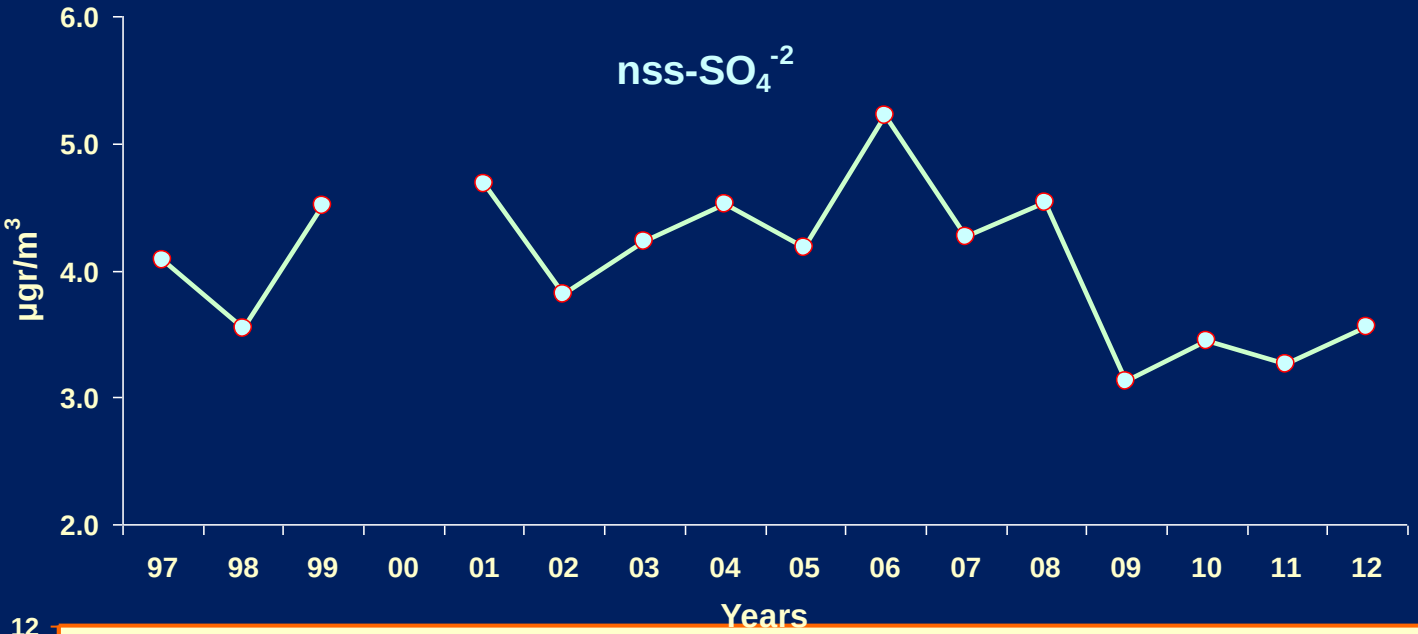
decreasing trend
30%

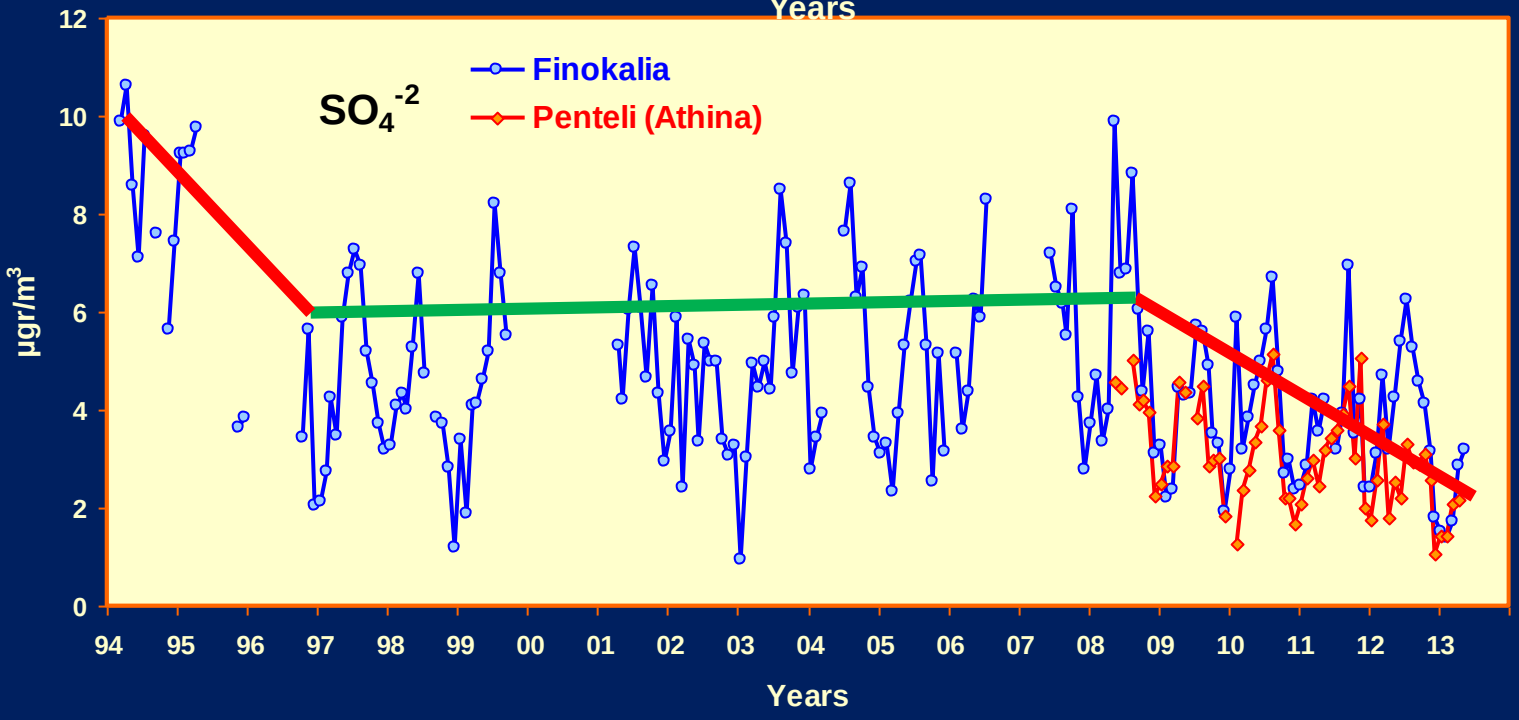


Rain Finokalia



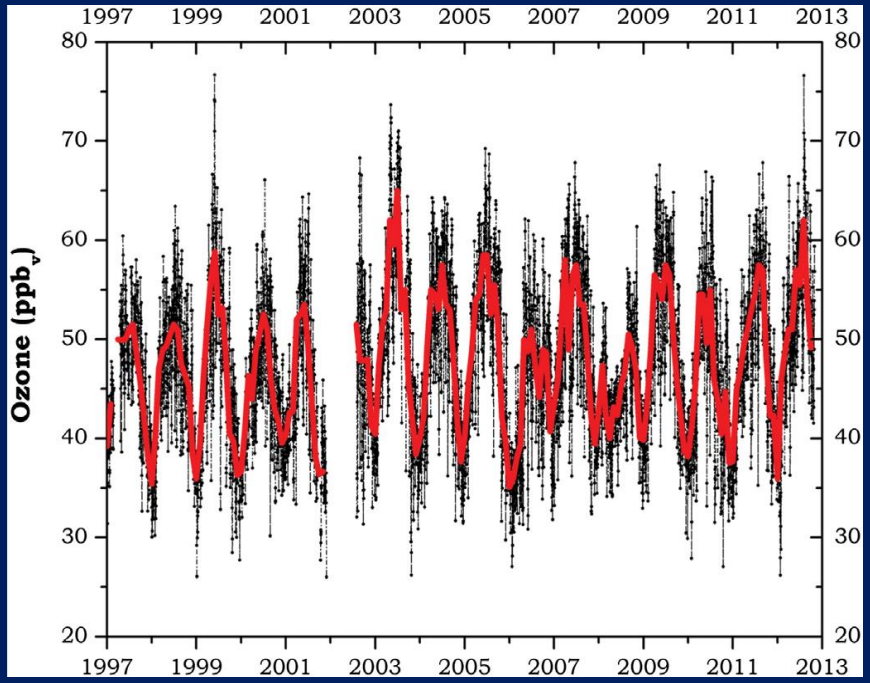



nss-SO4-2
µgr/m3
6.0
5.0
4.0
3.0
2.0
97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12
Years


SO4-2
Finokalia
Penteli (Athina)
µgr/m3
12
10
8
6
4
2
0
94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13
Years

Trace gases characterization: Ozone (Agia Marina)

Ozone (O_3) variability

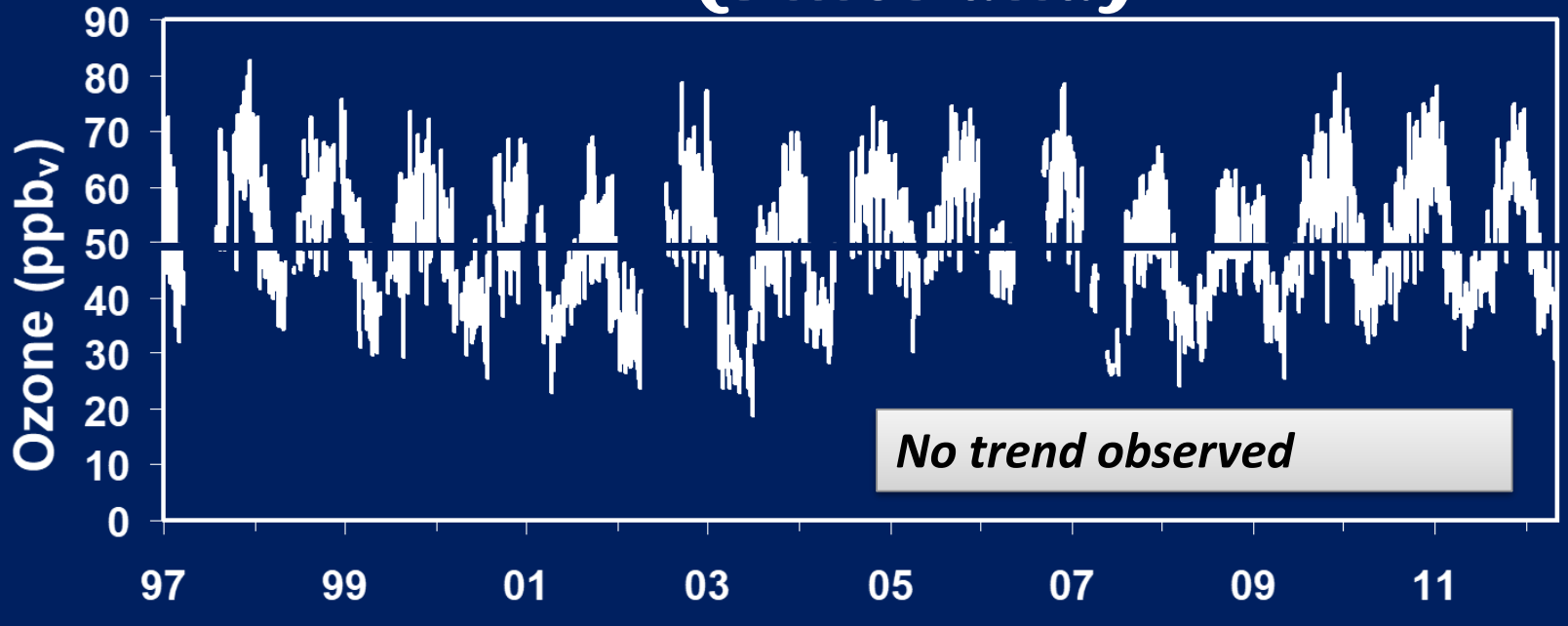


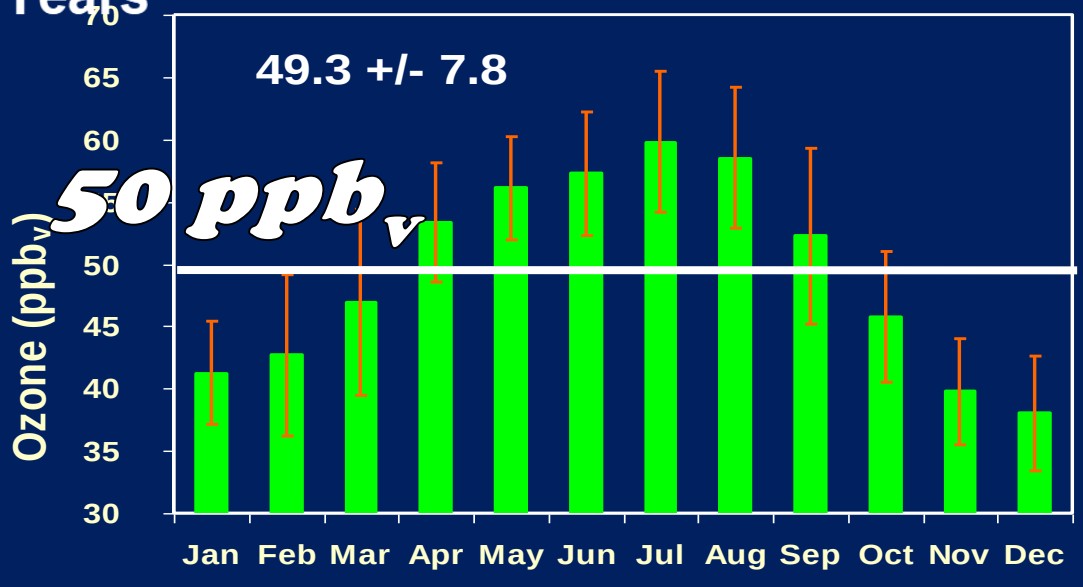
No trend observed

Kleanthous, Vrekoussis et al., 2014, STOTEN

Local emissions impact on ozone levels is small

Trace gases characterization: Ozone (Finokalia)

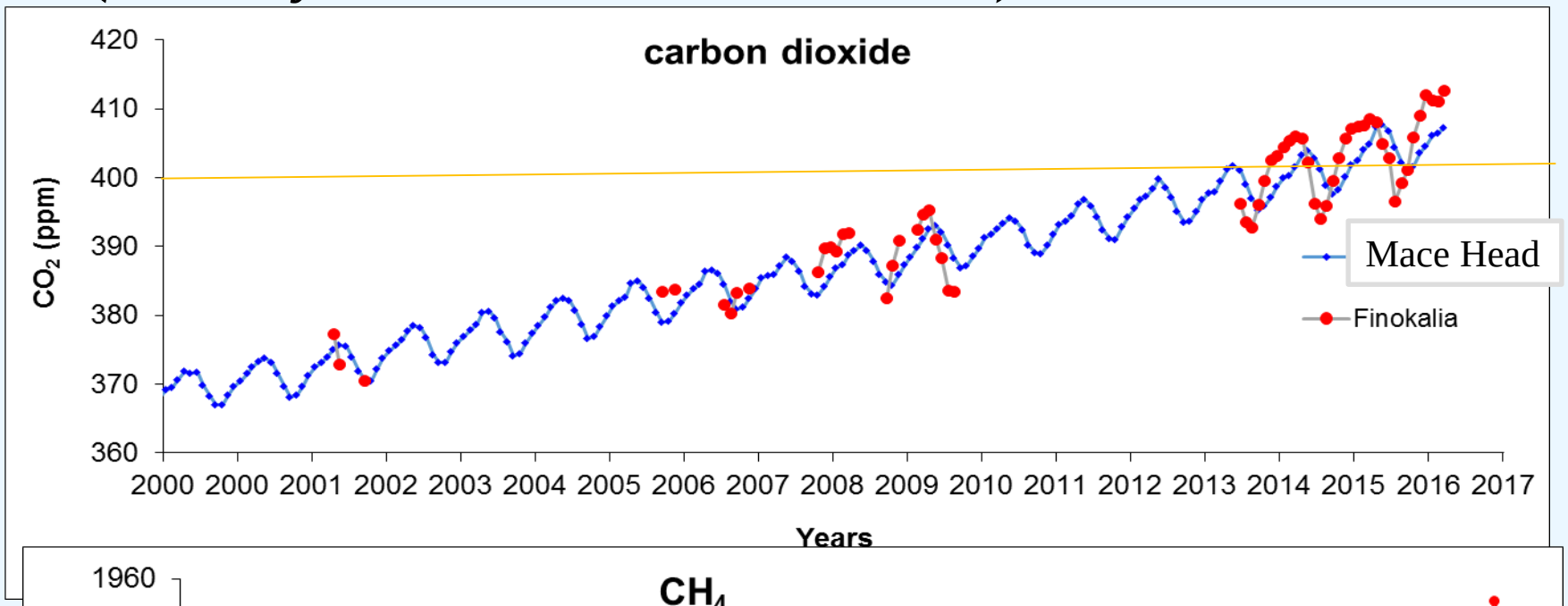


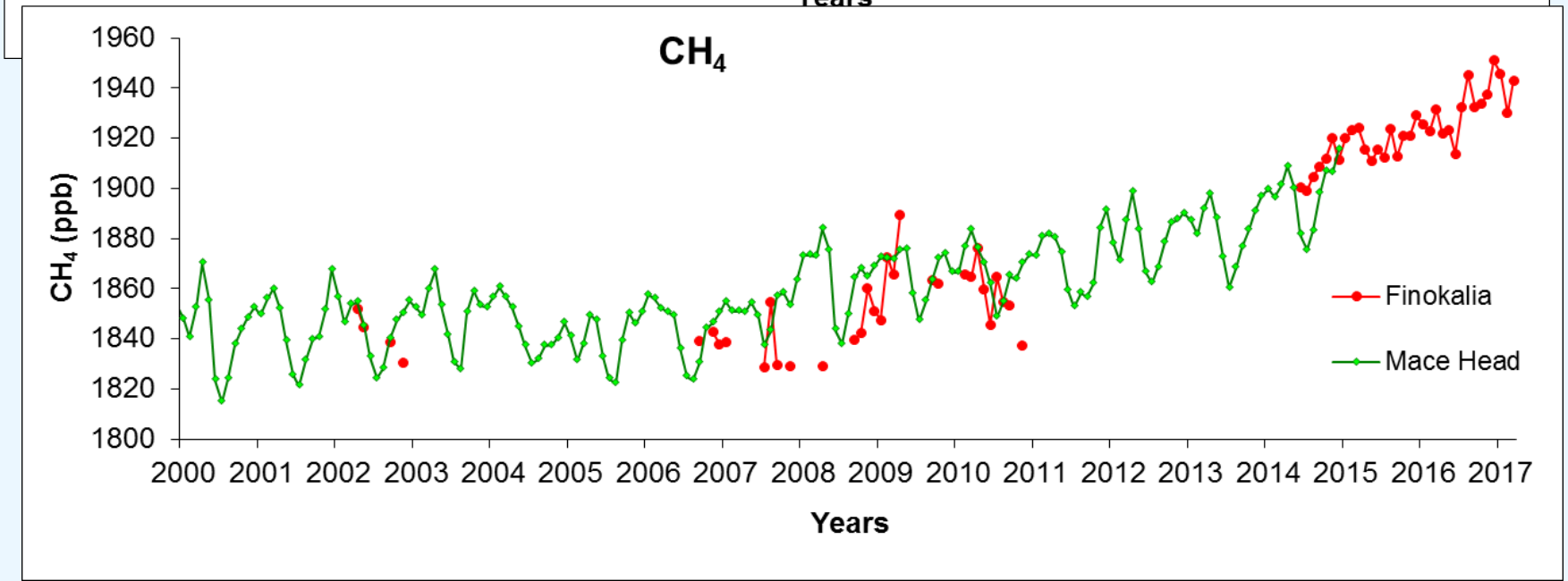


Exceeding the 50 ppbv 8h limit in Summer

ICOS
(Integrated Carbon Observation System)

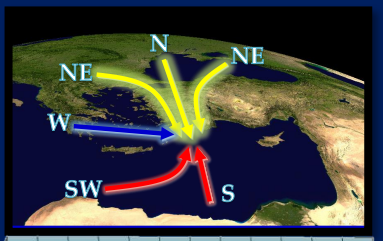
Greenhouse gases measurements at Finokalia Crete (Courtesy M. Ramonet, LSCE, France) EU ICOS network



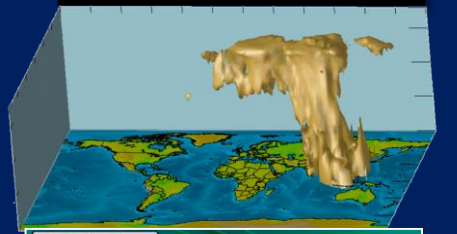


Conclusions

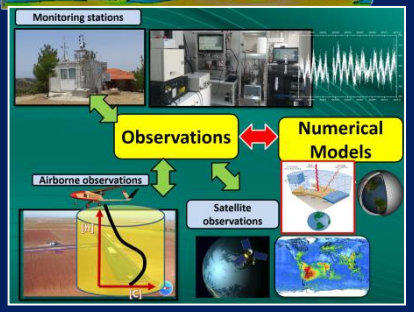
Lower troposphere strongly polluted by European emissions



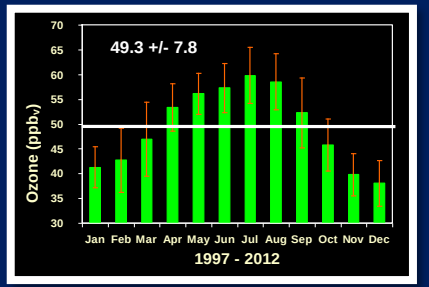
Upper tropospheric pollution from S-Asia even penetrates the lower stratosphere



Continuous monitoring of atmospheric composition using a combination of ground based stations, satelites 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.

Heraklion, Crete - Greece