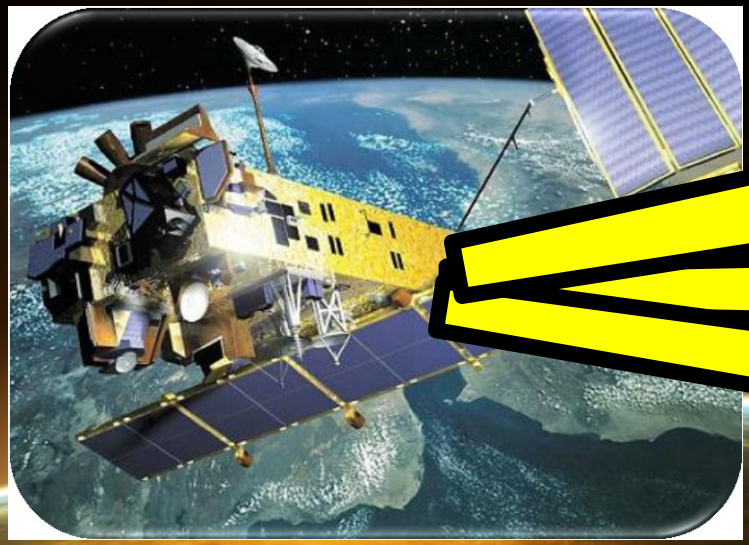
Economic Crisis Detected from Space:



Trends in Air Quality of Athens/Greece.

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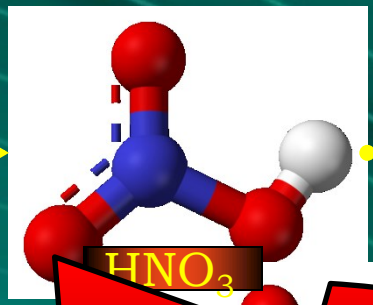
PRESCRIBE 2013

ACCENT Plus
ATMOSPHERIC COMPOSITION CHANGE
THE EUROPEAN NETWORK

THE CYPRUS INSTITUTE	The Energy, Environment and Water Research Center (EEWRC): The Cyprus Institute, Nicosia, **Cyprus.**	M. Vrekoussis, L. Barrie, J. Lelieveld and N. Mihalopoulos
iup	Institute of Environmental Physics and Remote Sensing, University of Bremen, **Germany**	M. Vrekoussis, A. Richter, A. Hilboll and J.P. Burrows
ACADEMY OF ATHENS	Research Centre for Atmospheric Physics and Climatology, Academy of Athens, **Greece.**	M. Vrekoussis, C. Zerefos
ΕΘΝΙΚΟΝ ΑΣΤΕΡΟΣΚΟΠΕΙΟΝ ΑΘΗΝΩΝ NATIONAL OBSERVATORY ATHENS	Institute for Environmental Research and Sustainable Development, National Observatory of Athens, **Greece**	E. Gerasopoulos
	Environmental Chemical Processes Laboratory, Department of Chemistry, University of Crete, **Greece**	N. Mihalopoulos
	Max-Planck-Institute for Chemistry, Mainz, **Germany**	J. Lelieveld

Importance

OH



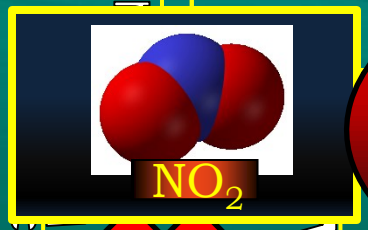
uptake

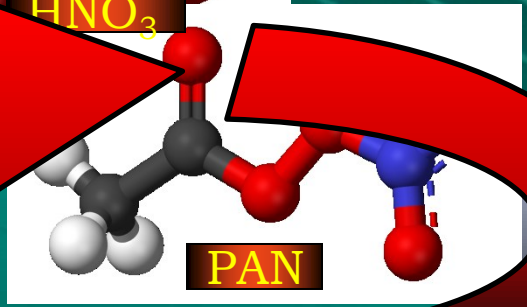
hν

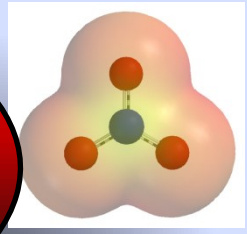
OH

surface reactions

RO_2



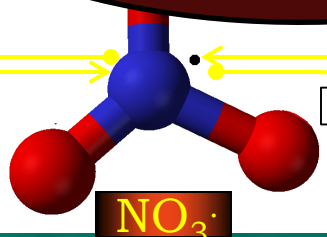




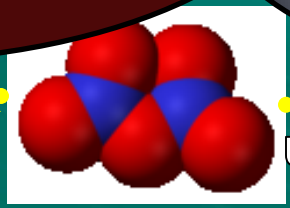
NO_3^-

RO_2,

hν



NO_2



uptake

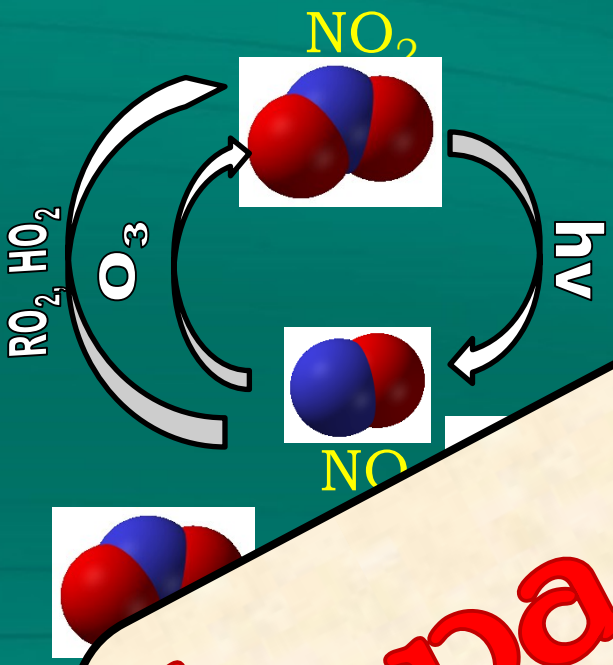
Emissions

deposition

(51%) (27%)

Why should we care about NOx in the Troposphere?

$NO_x = NO + NO_2$

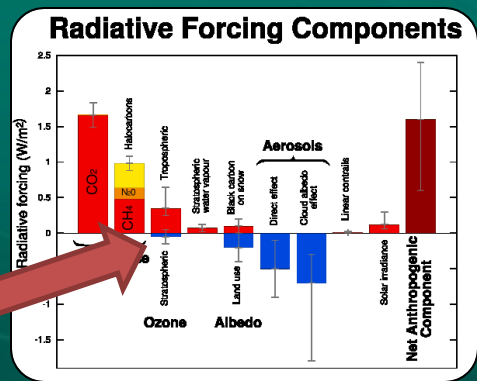


Impact on climate and human health

…tion, NO_3^-
…OH, $NO_3 \rightarrow N_2O_5$)
→ Acid rain, changes in eutrophication

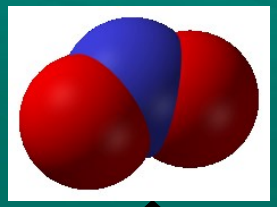
…es in radiative forcing
by absorbing sunlight
(locally)

Production of O_3: Greenhouse gas



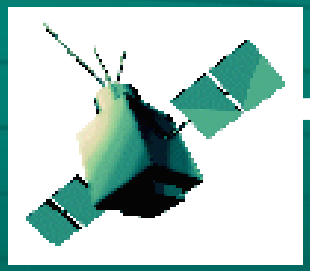
Emissions vs. observations

Short lifetime
(small background
concentrations)



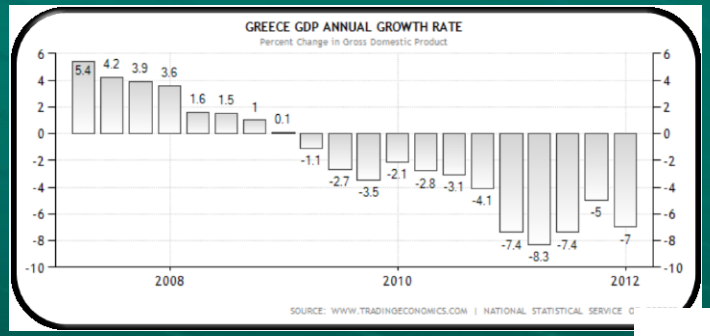
GOAL of the study

$$\frac{d(\text{  })}{dt} = f(\text{  })$$



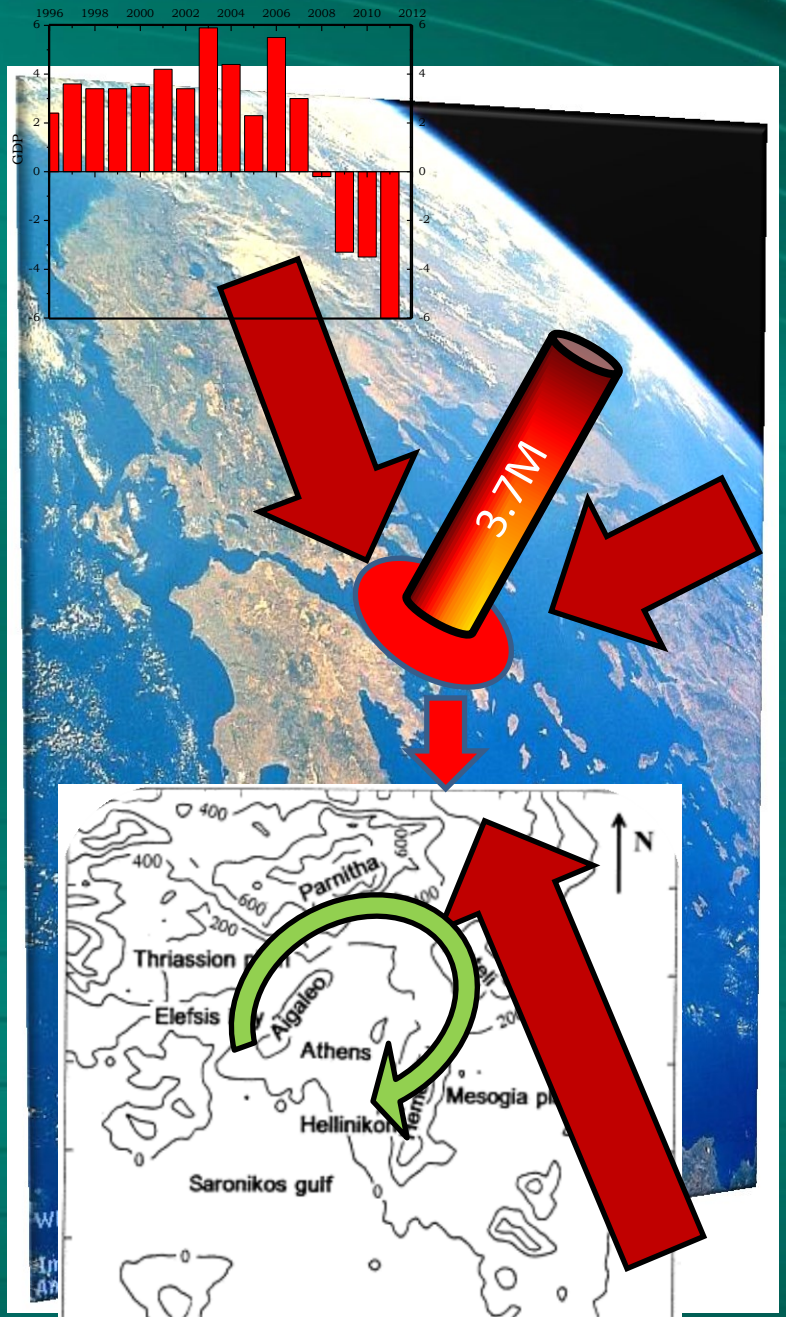
+

+



Location

Location of interest



GREECE :

Economic recession still continues (2008-today)

ATHENS:

Heavily polluted city

Gathers ~40% of total population with high populated density (up to 16k/km²)

Extensive number of registered vehicles
- **2.7M private cars,**
- **0.3M professional trucks**
- **0.7M motorcycles.**

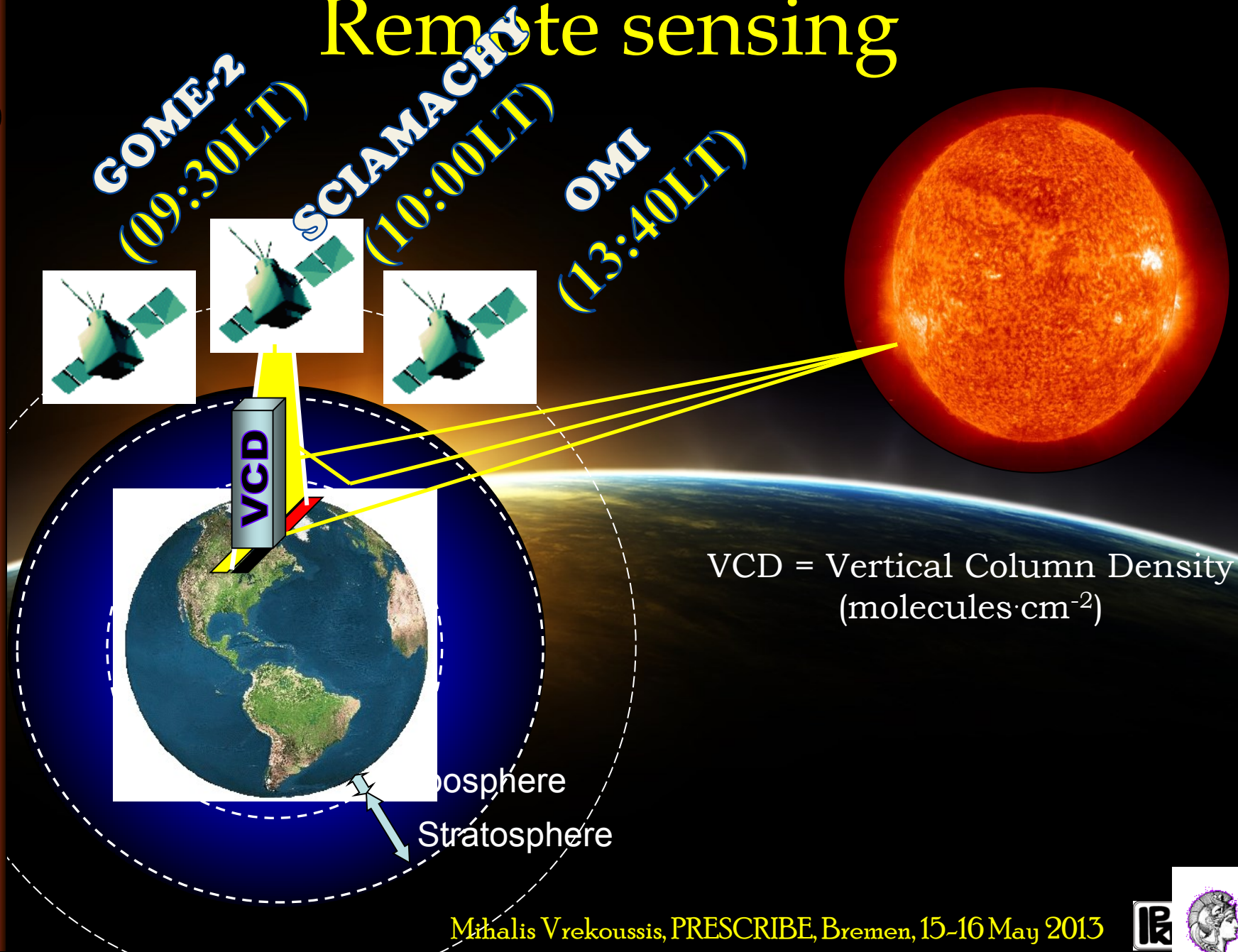
Industrial regions nearby

Complex topography-City surrounded by mountains

Belongs to East Mediterranean, an area of high photochemical activity and the crossroad of transported air masses of different origin.

Instrumentation

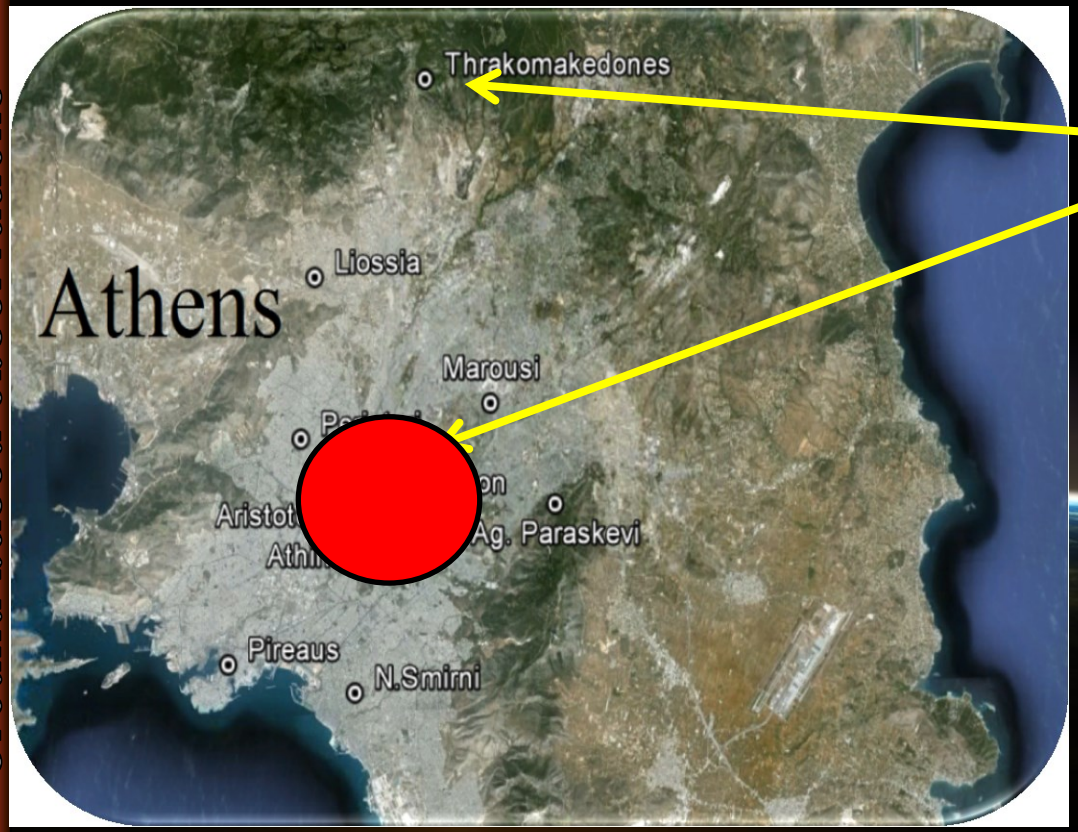
Remote sensing



VCD = Vertical Column Density
(molecules·cm^{-2})

In-situ measurements (Monitoring stations)

Ground-based observations



Data collected at 10 monitoring stations

Urban and suburban sites.

Commercial instruments:

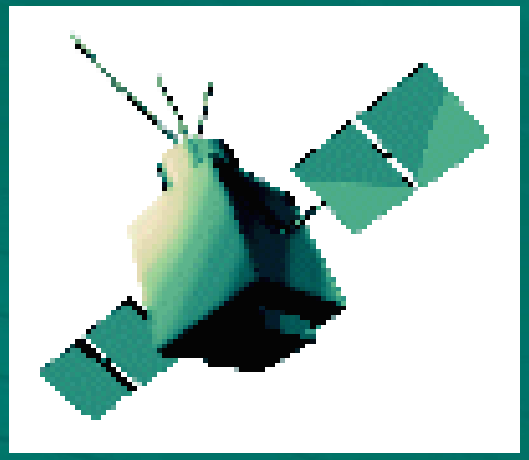
NO, NO_2*: Chemiluminescence

O_3: UV-absorption

CO: IR absorption

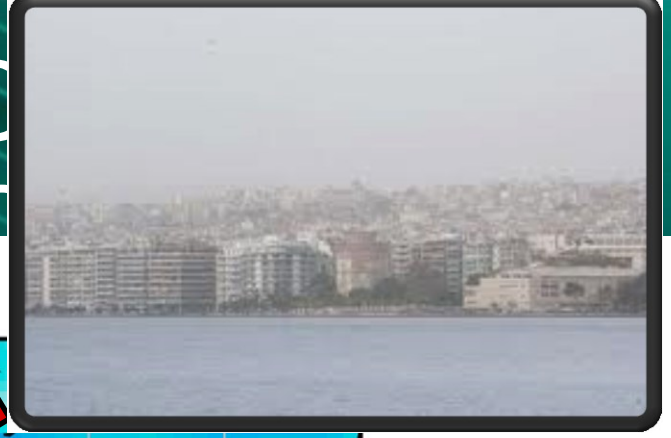
SO_2: UV-fluorescence

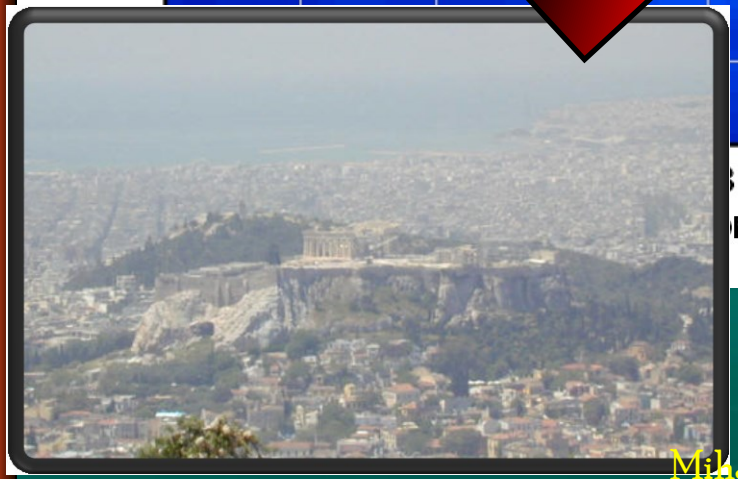
1. Results (satellites)

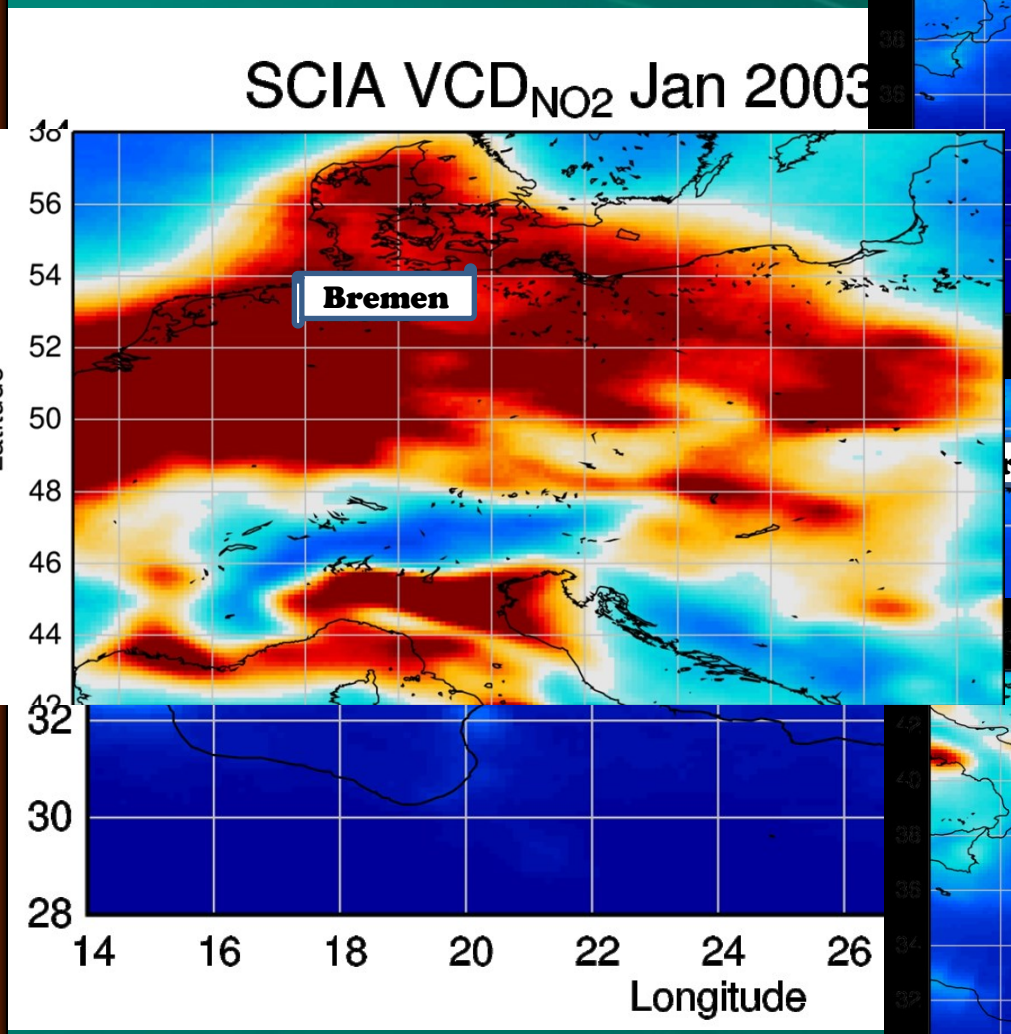


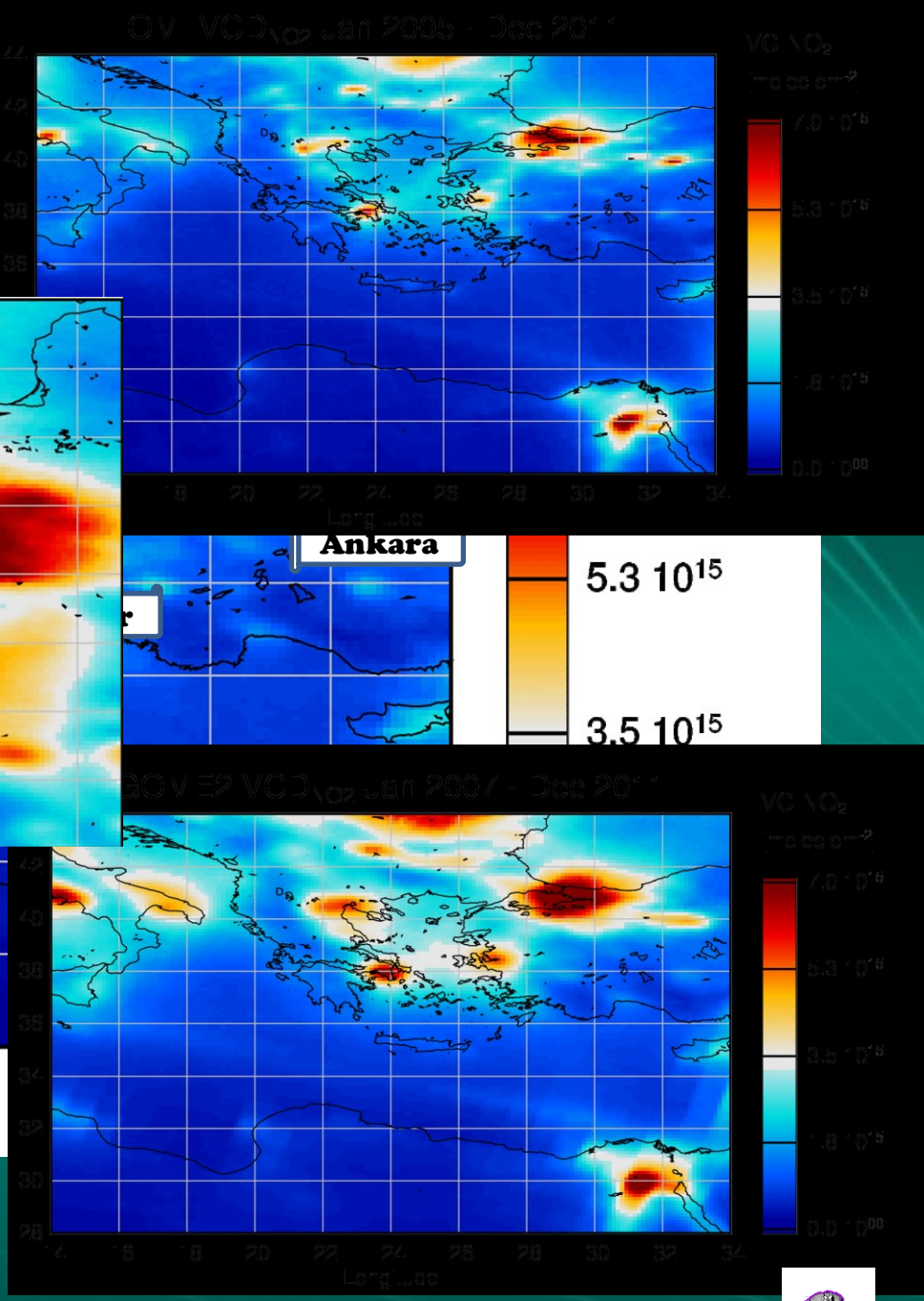
Trop. VCD NO$_2$ SCIAMAC

Results (satellite observations)



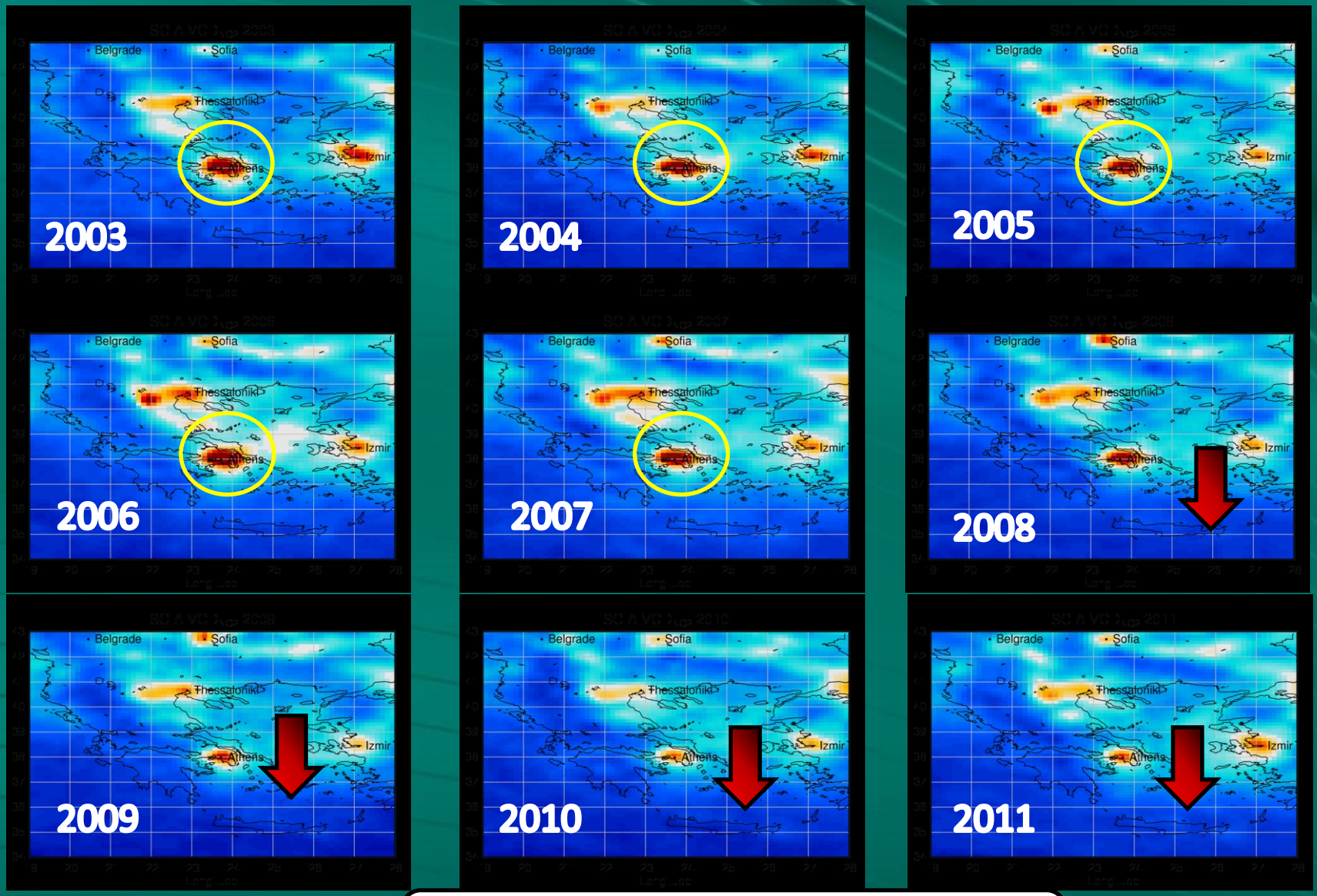



SCIA VCD$_{NO2}$ Jan 2003
Bremen
Latitude
Longitude
56
54
52
50
48
46
44
42
32
30
28
14
16
18
20
22
24
26

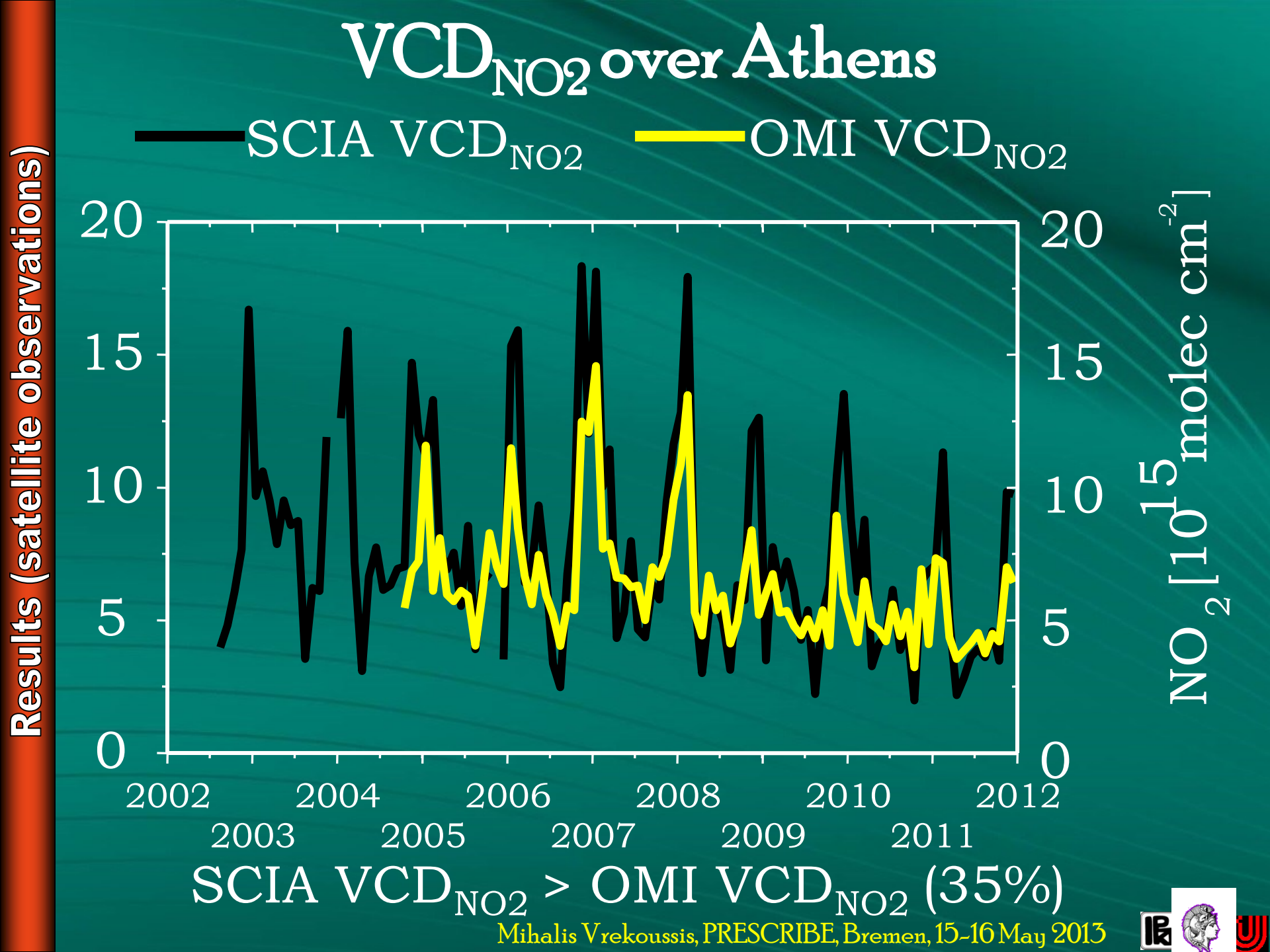

Ankara
5.3 10^{15}
3.5 10^{15}

Annual composite VCD NO_2 maps: SCIAMACHY

Results (satellite observations)



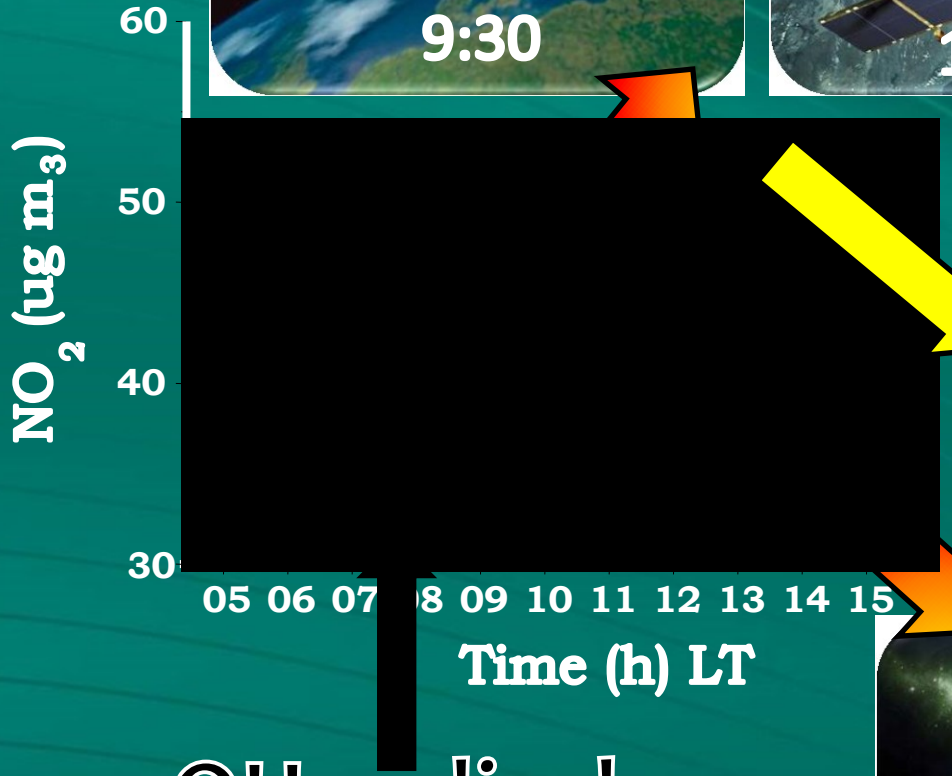
VCD_{NO2} over Athens



SCIA VCD_{NO2} > OMI VCD_{NO2} (35%)

Results (satellite observations)

Temporal (dial) dependence

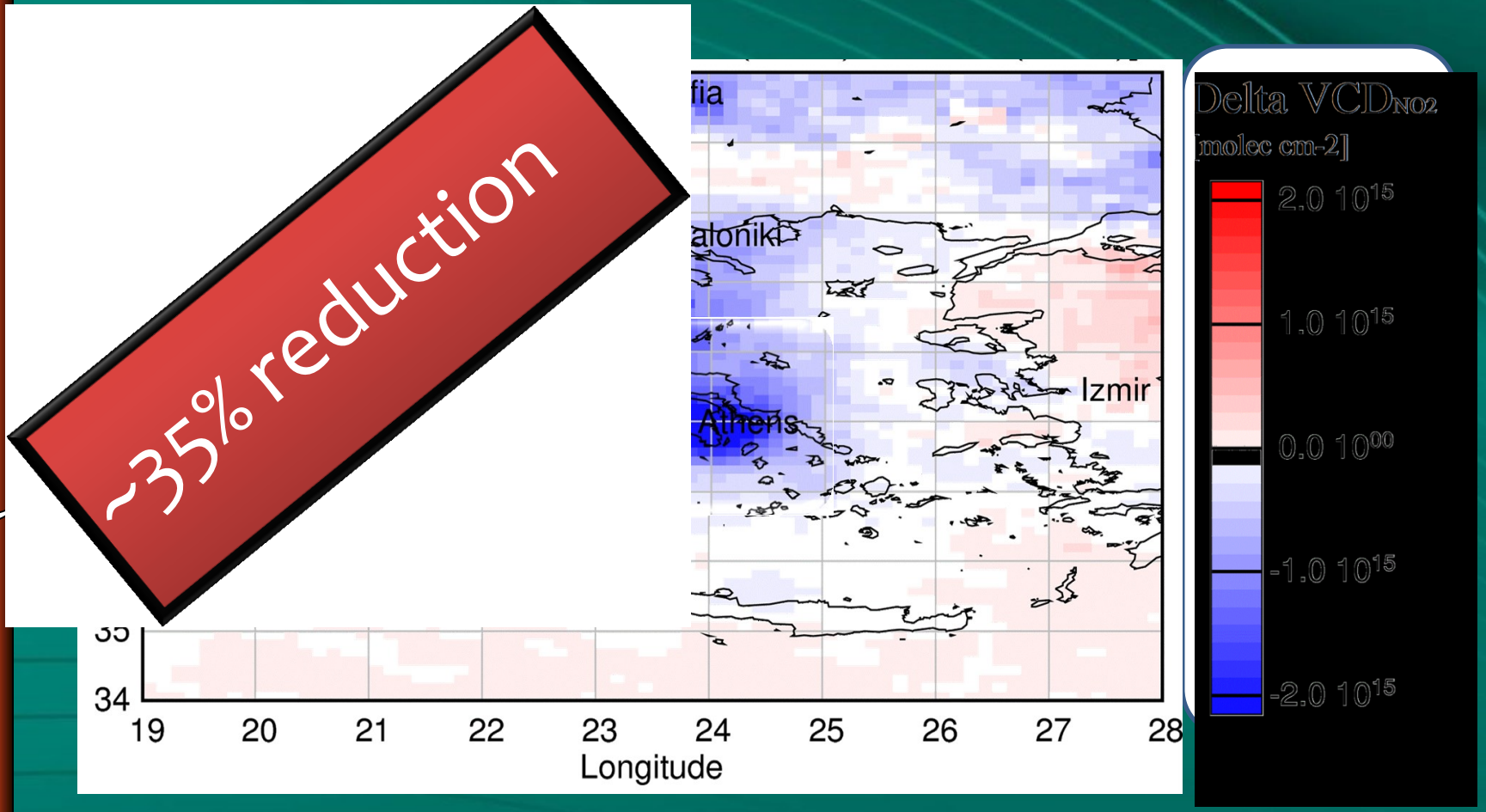


High OH,
NO_2+OH->HNO_3

OH radicals

Results (satellite observations)

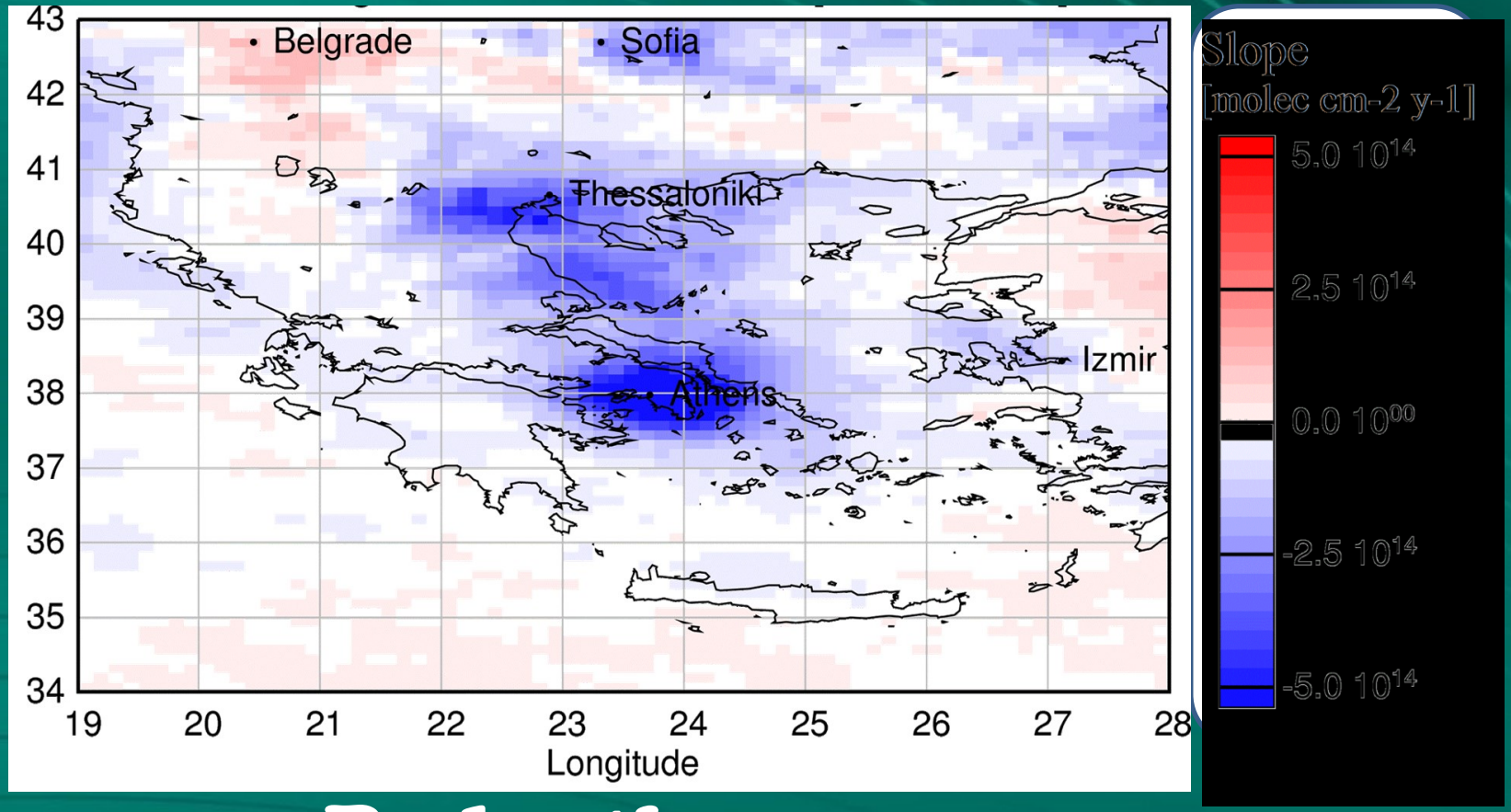
Delta of the GOME2 VCD_{NO2} [2011] – [2007]



Reduction > $3 \cdot 10^{15}$ molec cm^{-2}

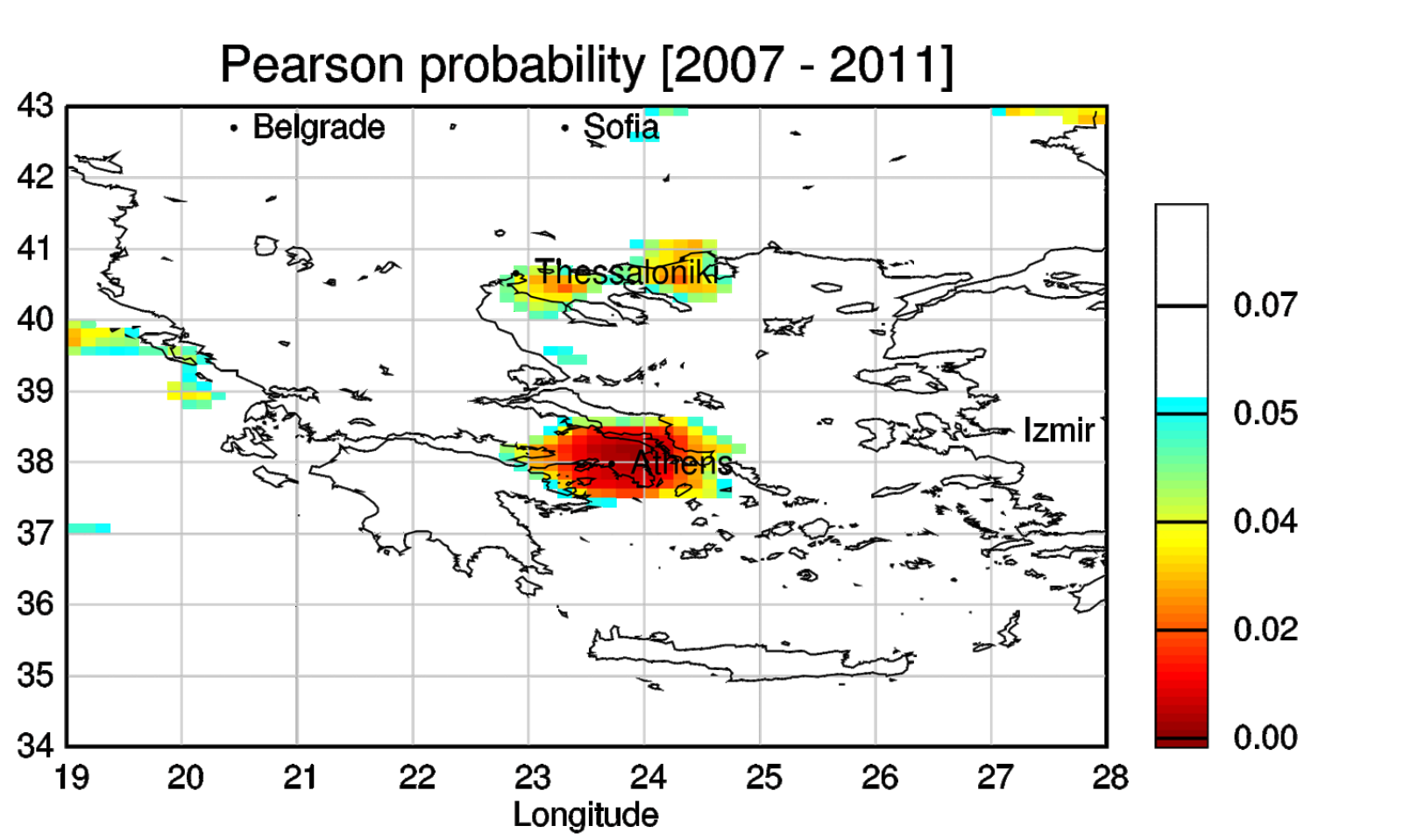
Results (satellite observations)

Linear regressions of the GOME2 VCD_{NO_2} 2007 to 2011



Reduction per year ~$1 \cdot 10^{15}$ molec $cm^{-2}y^{-1}$

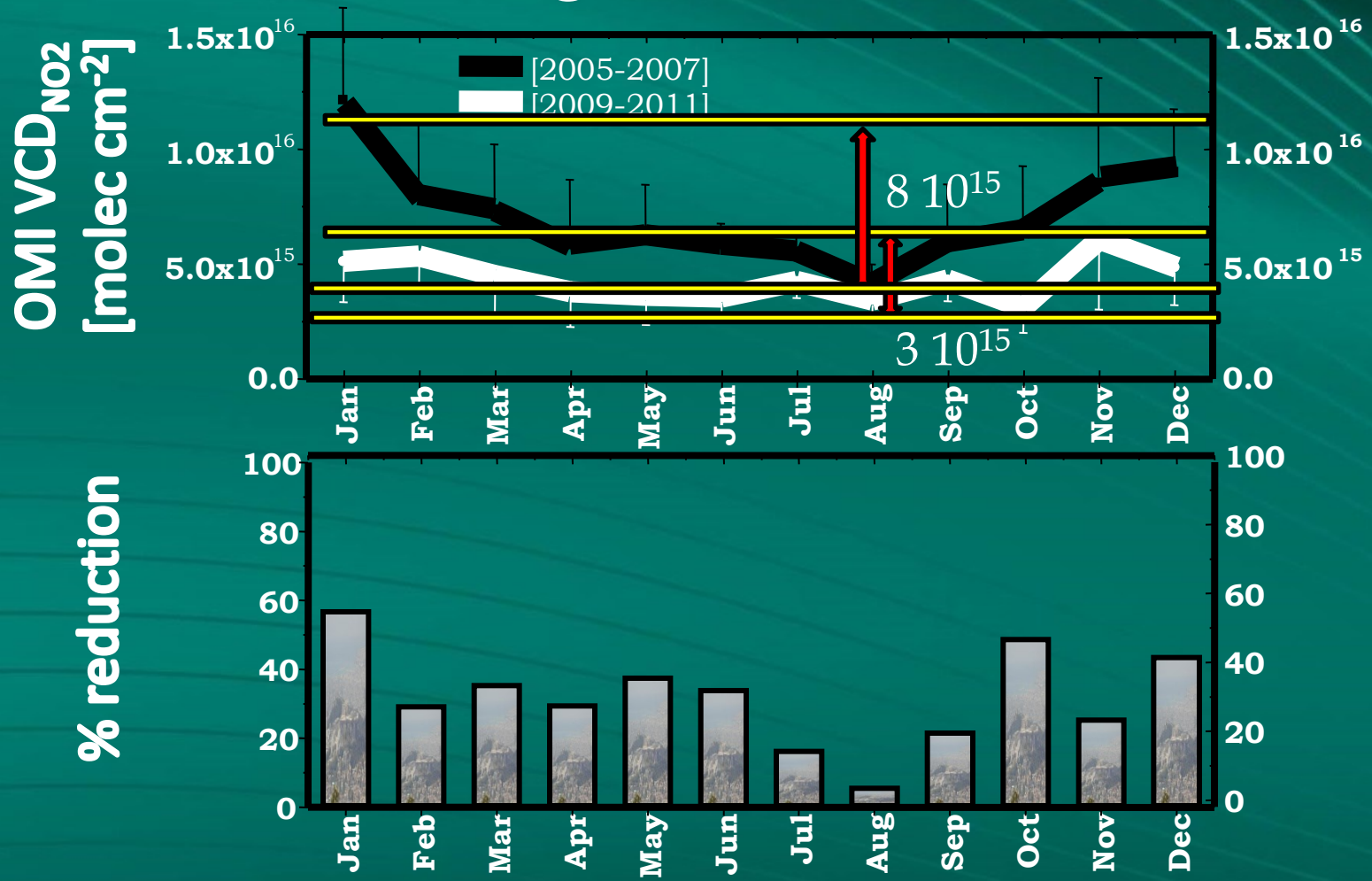
Significance?



Significant trend at 95% confidence level (Pearson test)

Results (satellite observations)

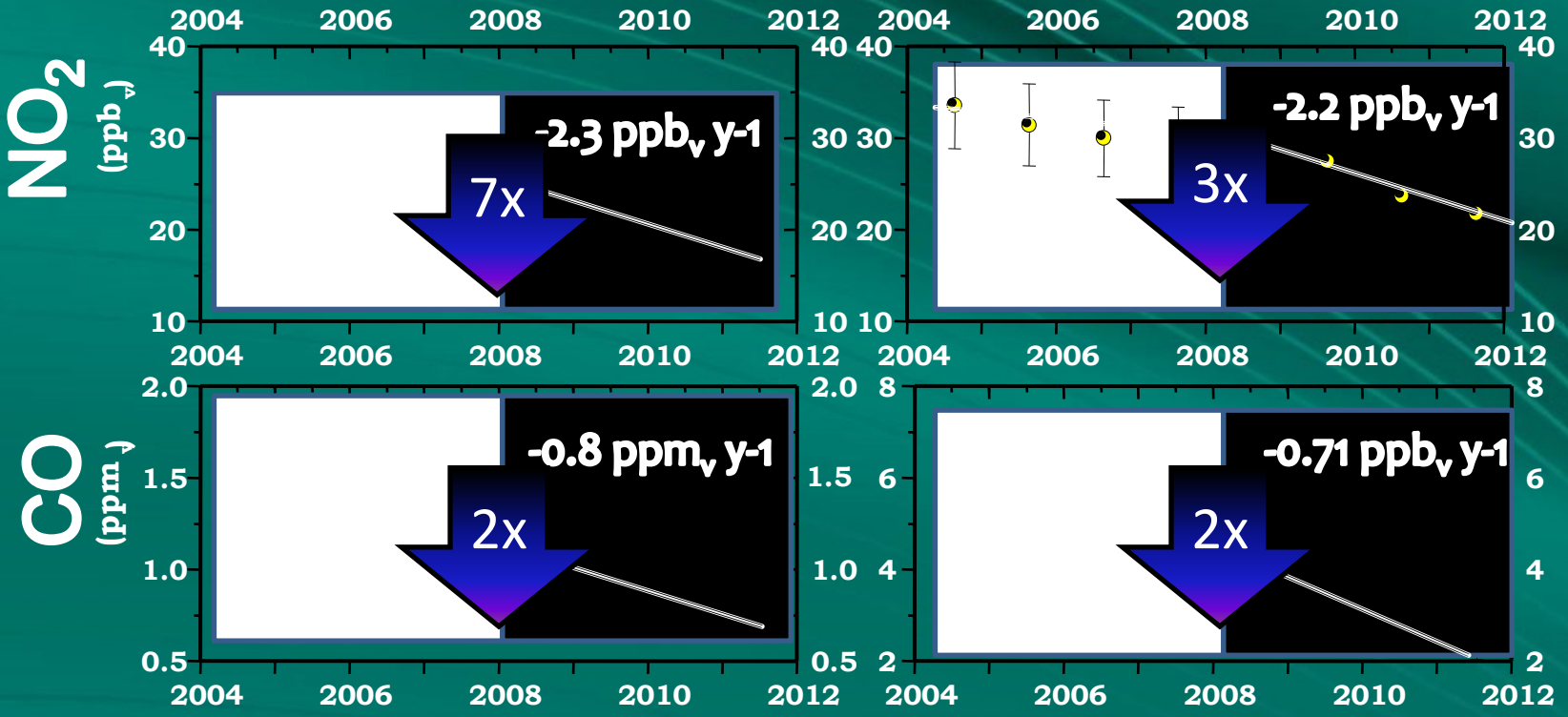
Seasonal changes in VCD levels before and during economic recession

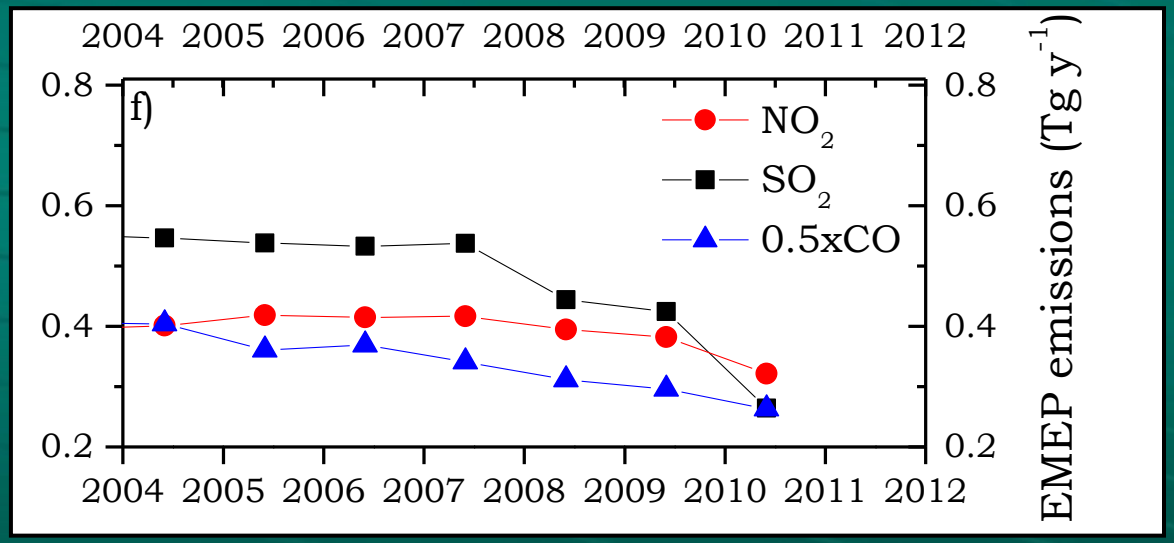


2. in situ NO_2 measurements in Athens

in situ measurements

Results (ground-based observations)





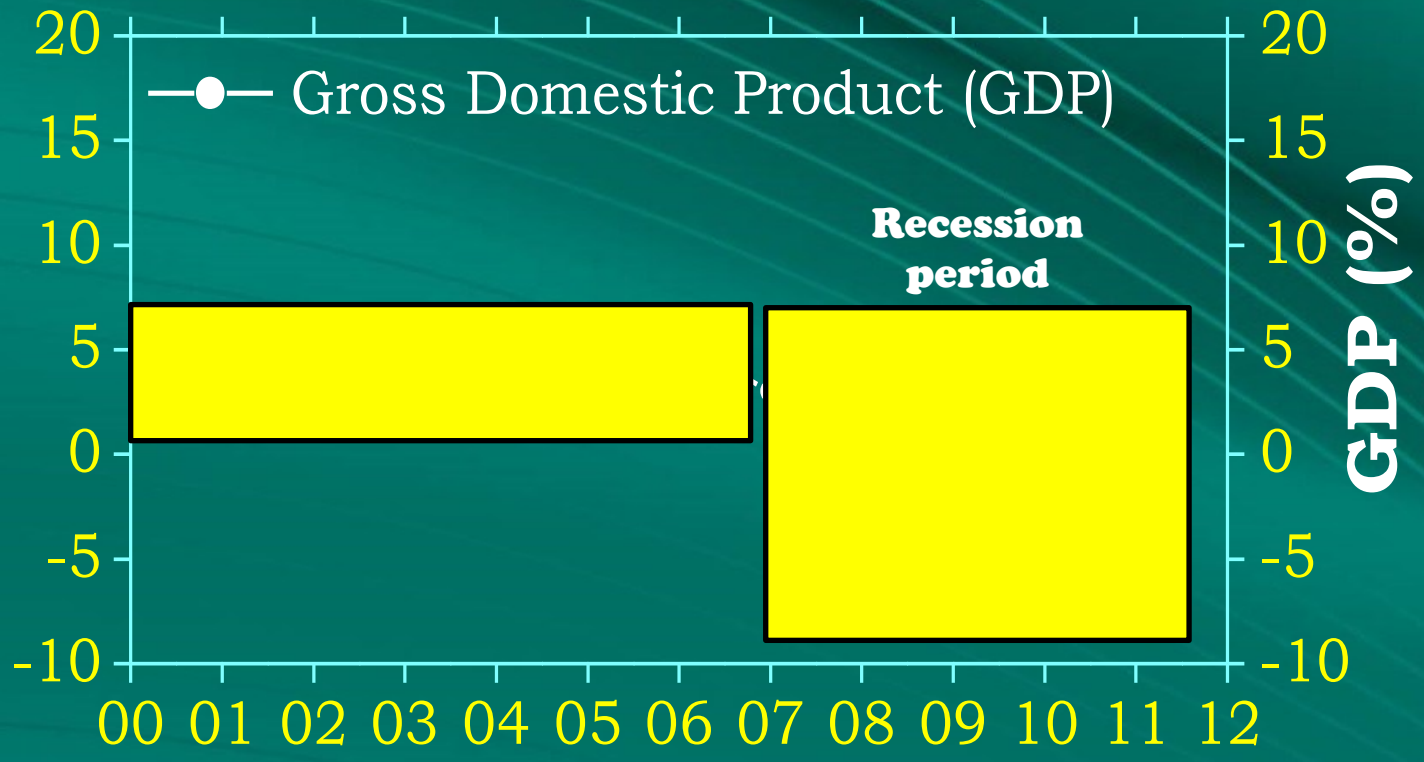
3. **Economic metrics.**

Indicator 1:

Gross Domestic Product (GDP)

The GDP is a primary indicator to gauge a country's standard of living. "The total value of all the goods and services produced within a country's borders is described as its gross domestic product."

(Dictionary of Financial Terms)

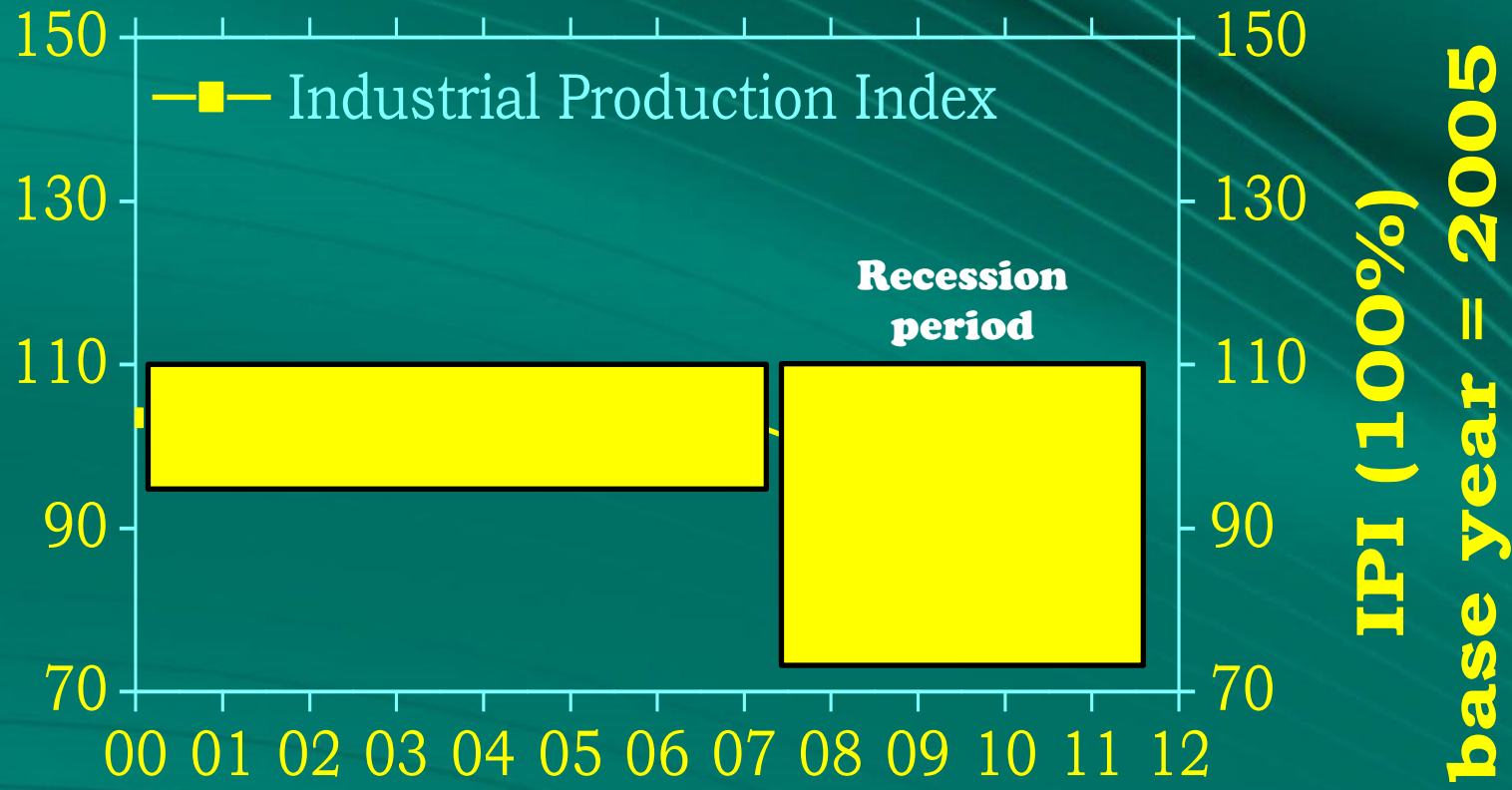


Source: European Commission Statistics, Eurostat, http://epp.eurostat.ec.europa.eu/

Indicator 2:

Industrial Production Index (IPI)

The IPI is an economic indicator which measures **real production output**, which includes manufacturing, mining, and utilities. It is expressed as a percentage of real output with base year currently at 2005.

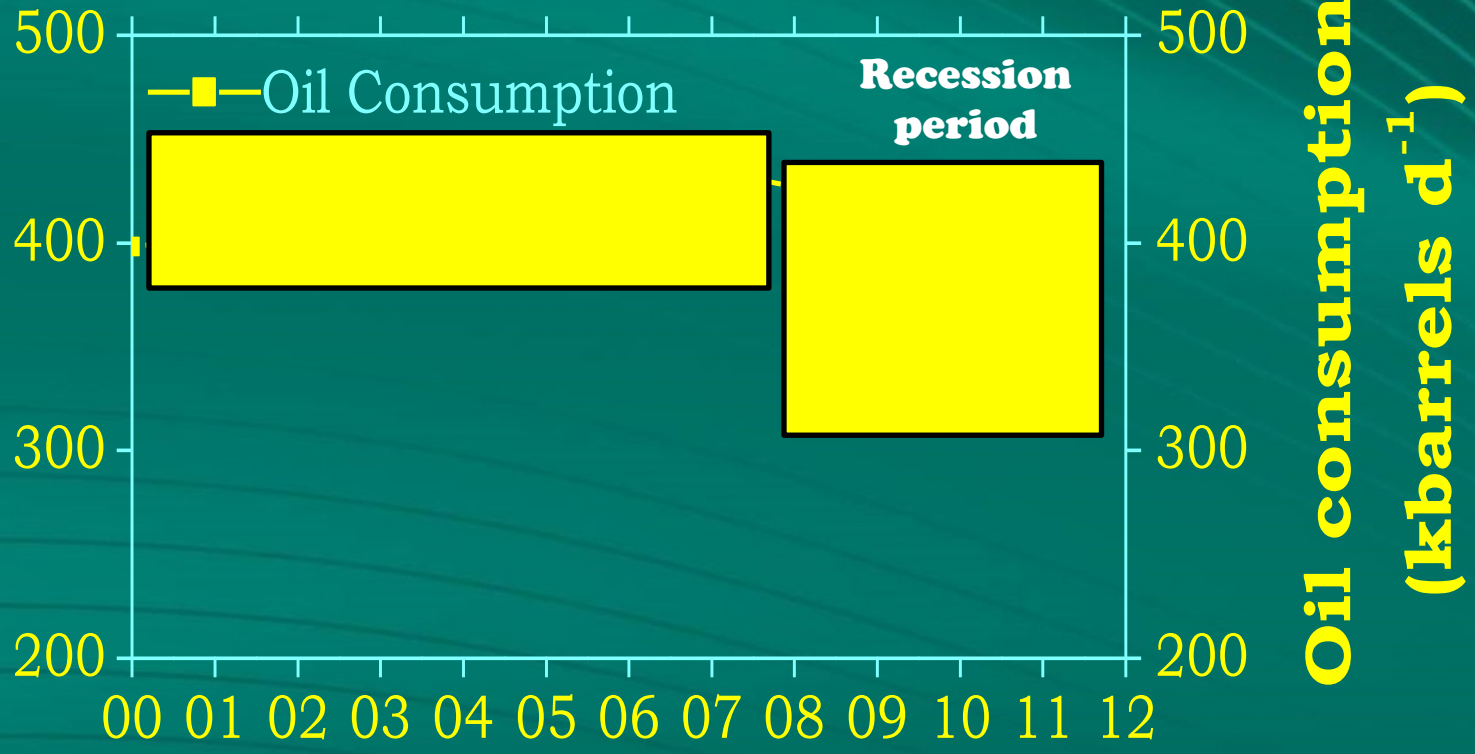


Source: Hellenic Statistical Authority (El-stat): http://www.statistics.gr

Indicator 3:

Oil Consumption (in k barrels d^{-1})

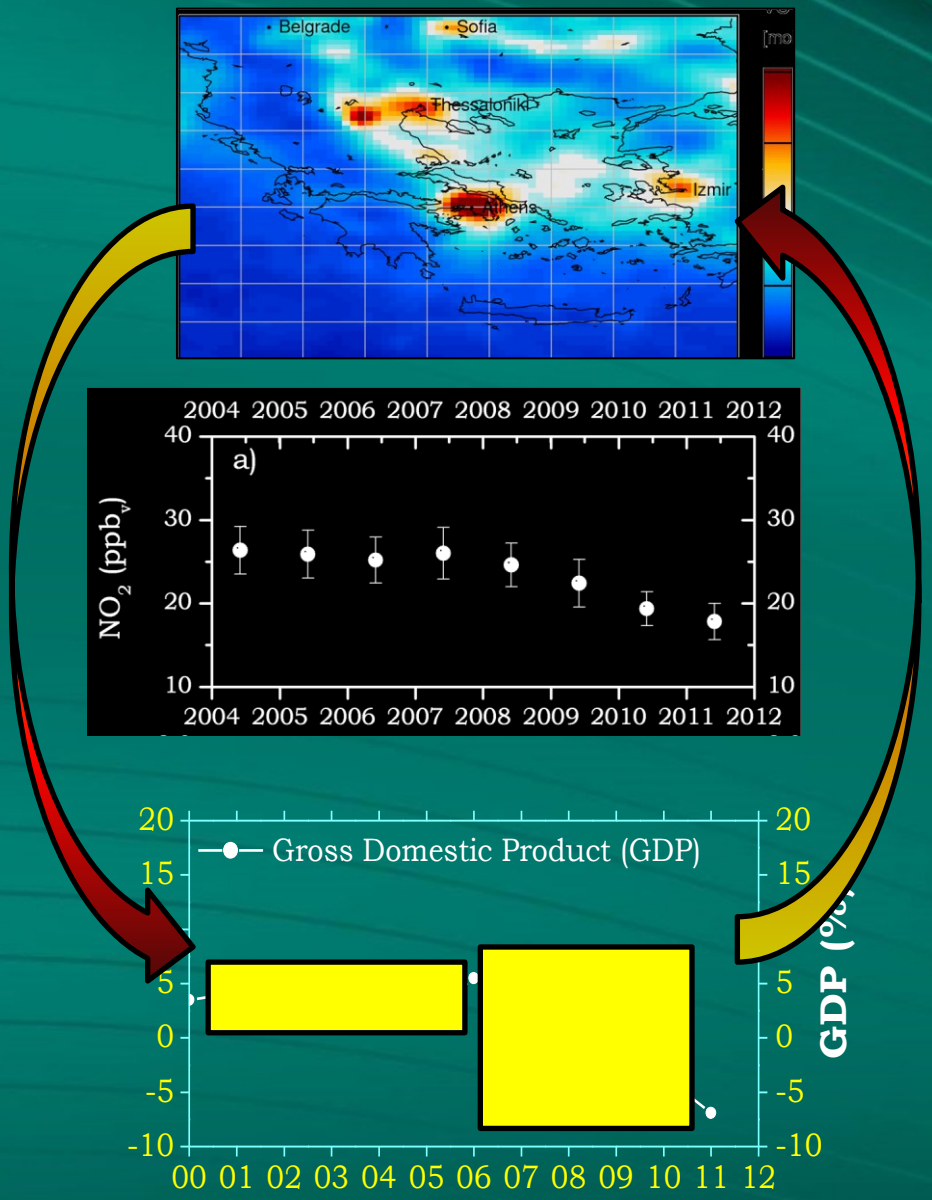
Economic metrics



source: Statistical review of world Energy, http://www.bp.com

Observations vs. economic metrics

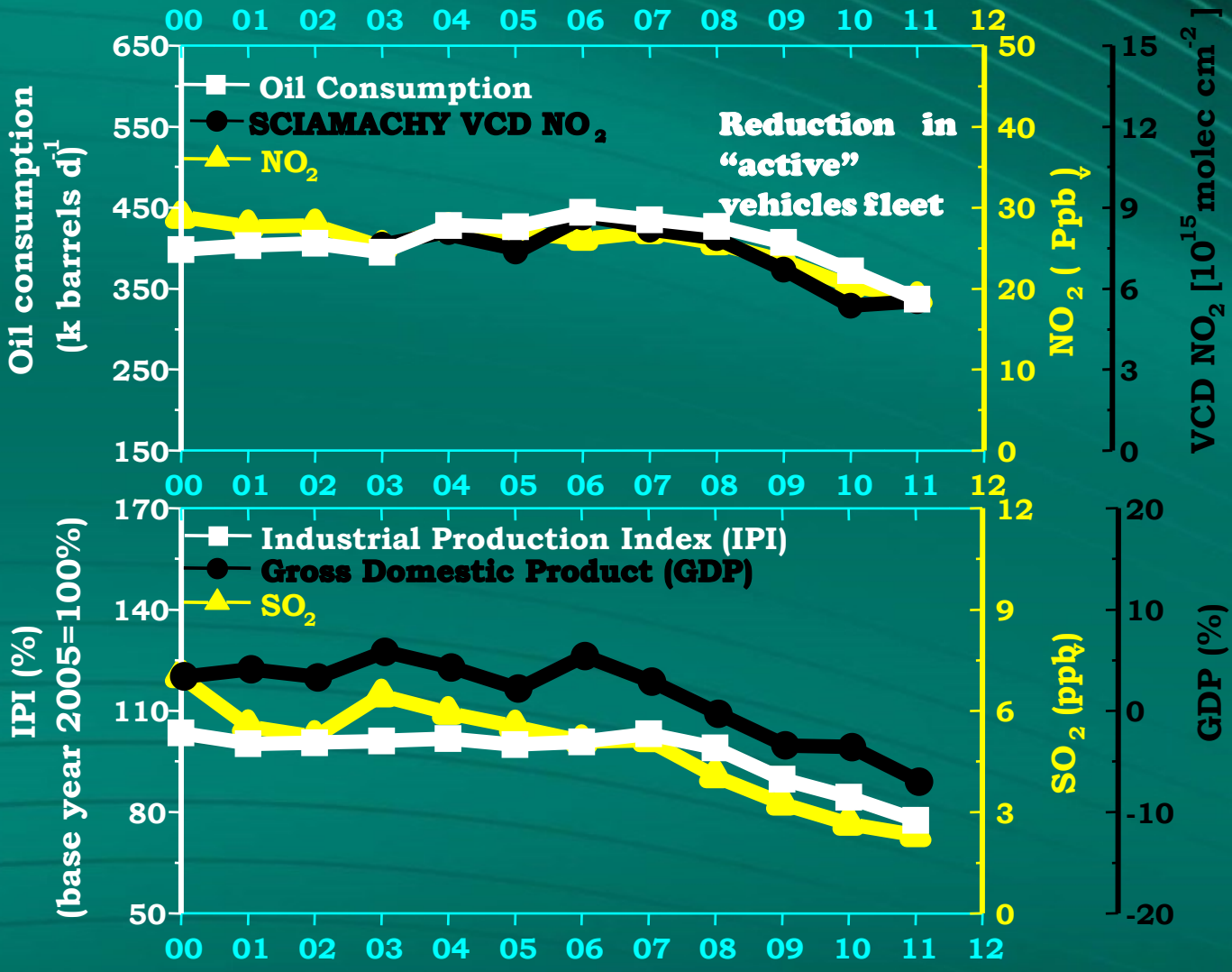
Results



Space-based observations

Ground-based observations

Economic metrics



GDP still drops:

Distinct change in anthropogenic activities

Lower local pollutant emissions

Conclusions

Conclusions

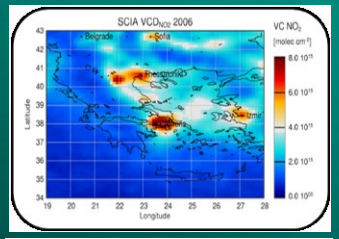
- Pollution **(over Athens)** is traceable from space.

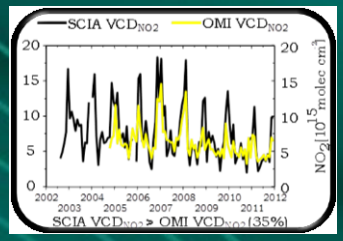
Since 2008 onward, NO_2 tropospheric levels dropped **by 30-40%**

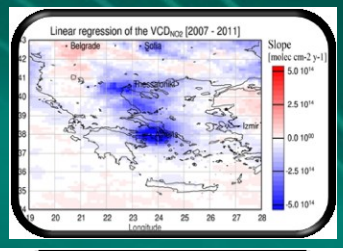
A significant reduction of **~$1 \cdot 10^{15}$ molec cm^{-2} y^{-1}** is computed over Athens.

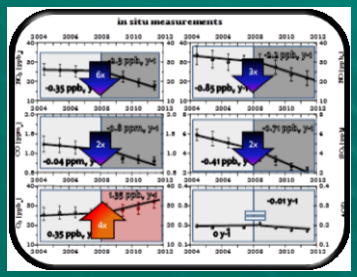
During the recession period, annual reduction of NO_2 and SO_2 concentrations **accelerated by 7 and 2 times respectively compared to 2004-2007 period.**

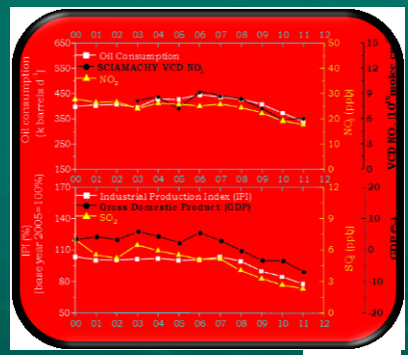
Economic metrics used as proxies of anthropogenic activities **significantly correlate with the observed reductions** in NO_2 and SO_2 emissions, tracked via the in-situ observations.





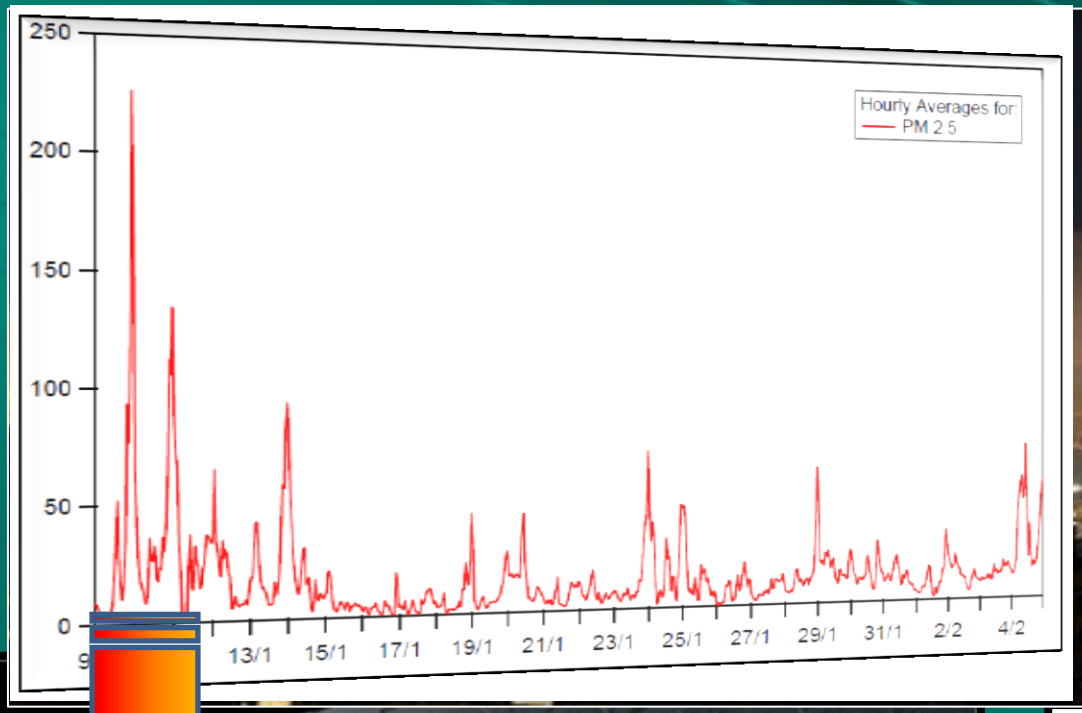


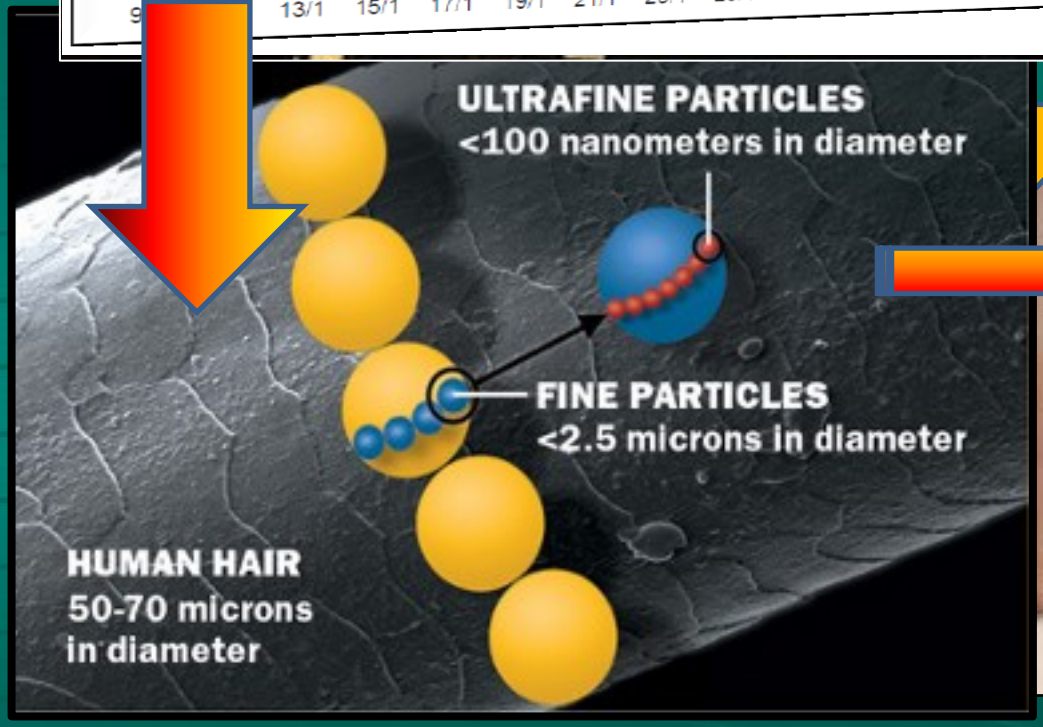


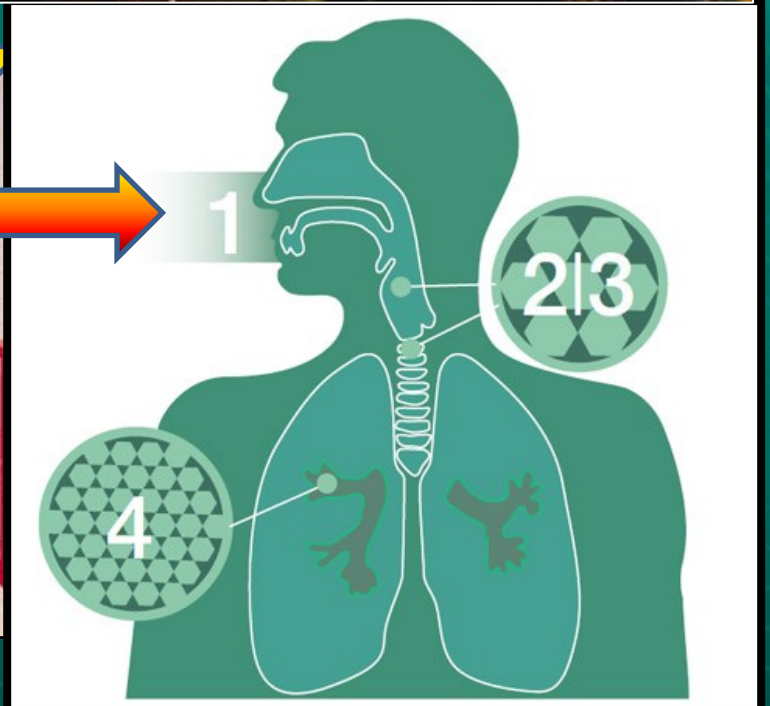


Reduction in NO_x and SO_x emissions led to improved environmental conditions thus lowered the potential of health risks

BUT…


250
200
150
100
50
0
Hourly Averages for:
PM 2.5
13/1
15/1
17/1
19/1
21/1
23/1
25/1
27/1
29/1
31/1
2/2
4/2


ULTRAFINE PARTICLES
<100 nanometers in diameter
FINE PARTICLES
<2.5 microns in diameter
HUMAN HAIR
50-70 microns
in diameter


1
2|3
4

Acknowledgments

Thank you for your attention

Sponsors

PARTHENO2N C8

MARIE CURIE ACTIONS

European Research Council

& megaCITY – Zoom for the Environment (CITYZEN)

ACCENT *Plus*
ATMOSPHERIC COMPOSITION CHANGE
THE EUROPEAN NETWORK

SEVENTH FRAMEWORK PROGRAMME


GEOPHYSICAL RESEARCH LETTERS, VOL. 40, 1–6, doi:10.1002/grl.50118, 2013

Economic crisis detected from space: Air quality observations over Athens/Greece

M. Vrekoussis,[1,2,3] A. Richter,[2] A. Hilboll,[2] J. P. Burrows,[2] E. Gerasopoulos,[4] J. Lelieveld,[5,6] L. Barrie,[1] C. Zerefos,[3] and N. Mihalopoulos[1,6]

Received 30 November 2012; accepted 24 December 2012.

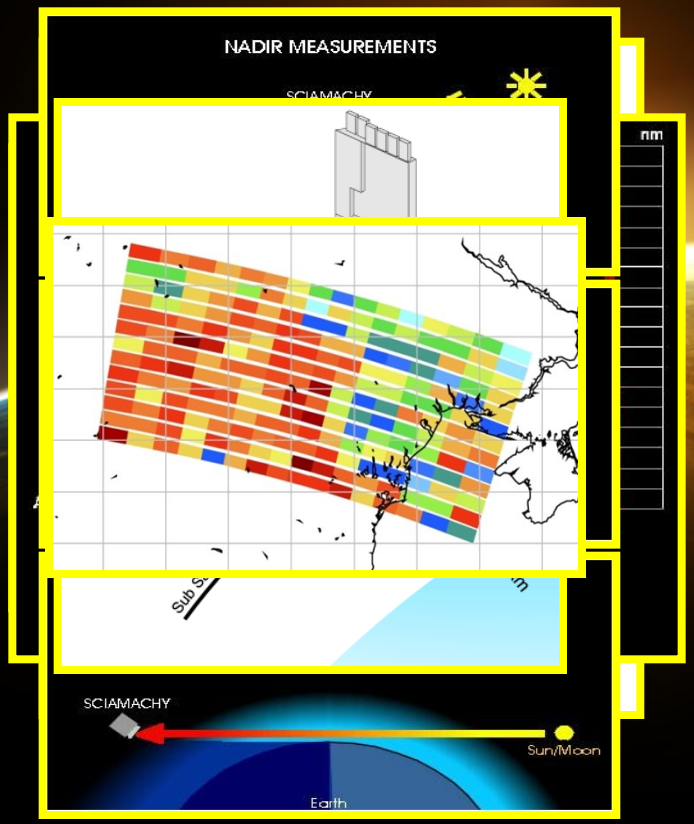
[1] Using both satellite observations of tropospheric NO_2 columns and a number of economic metrics, we investigate the impact of the economic crisis (from 2008 onward) on air quality over Greece, and Athens in particular. The multiannual analysis shows that NO_2 columns over Athens have been significantly reduced in the range 30–40%. This decline is further supported by surface measurements of atmospheric NO_2 mixing ratios. Additionally, the declining local concentrations of NO, CO, and SO_2 are associated with an increase in ozone due to reduced titration by NO. In

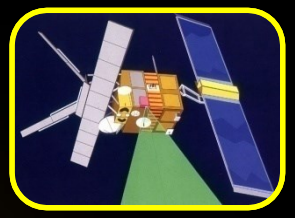
GRL: VOL. 40 (Jan), 1–6, 2013

Extra slides

Overview

SCIAMACHY, GOME-2, OMI

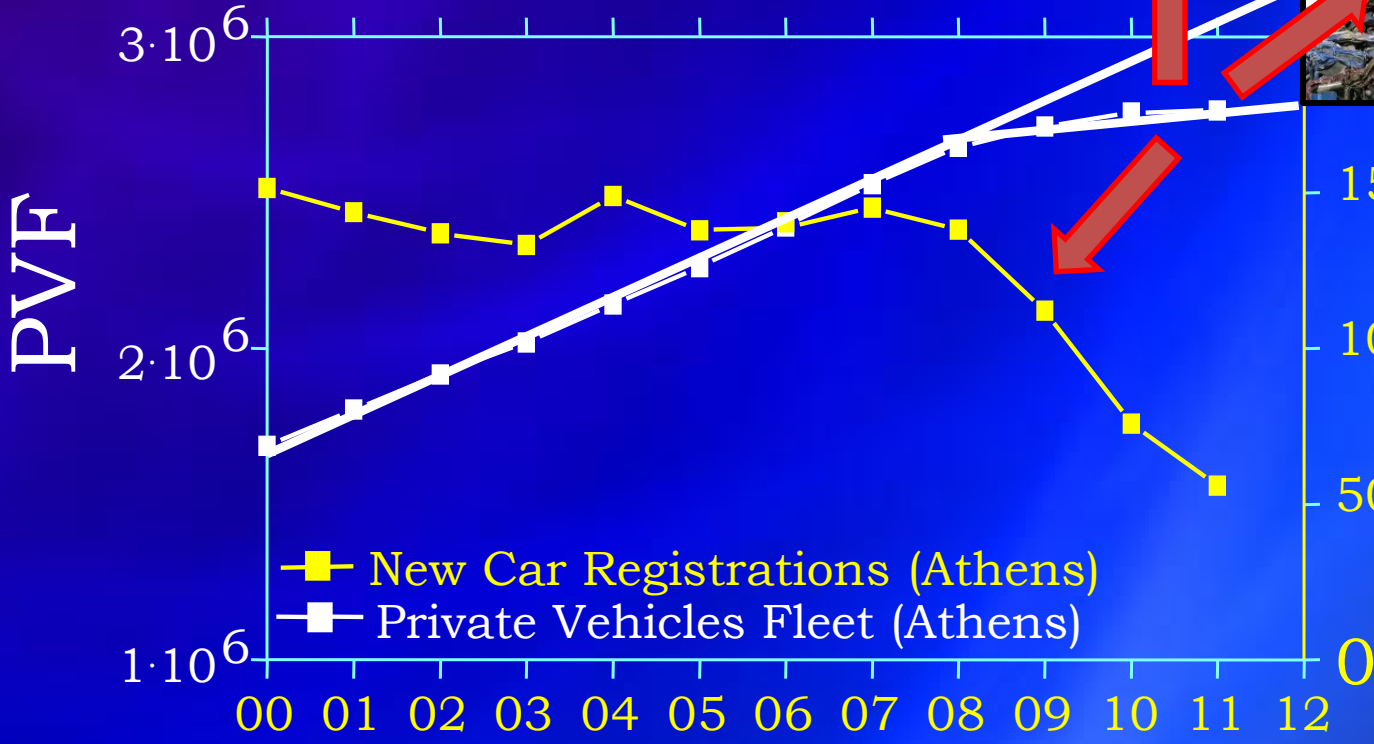




	OMI	SCIAMACHY	GOME-2
	Jul 2004 -today	Aug 2002 -Apr 2012	Jan 2007 -today
▶	Aura	Envisat	Metop
▶	**1**	**6**	**1.5 days**
▶	(260-504nm)	(240–2400 nm)	(240-790nm)
▶	(nadir)	(nadir, limb, occultation)	(nadir)
▶	2600km	960 km	1920km
▶	(13 x 24 km²)	(30 x 60 km²)	(40 x 80 km²)

Results

Indicator 4:
Private Vehicles Fleet
New vehicle licensing

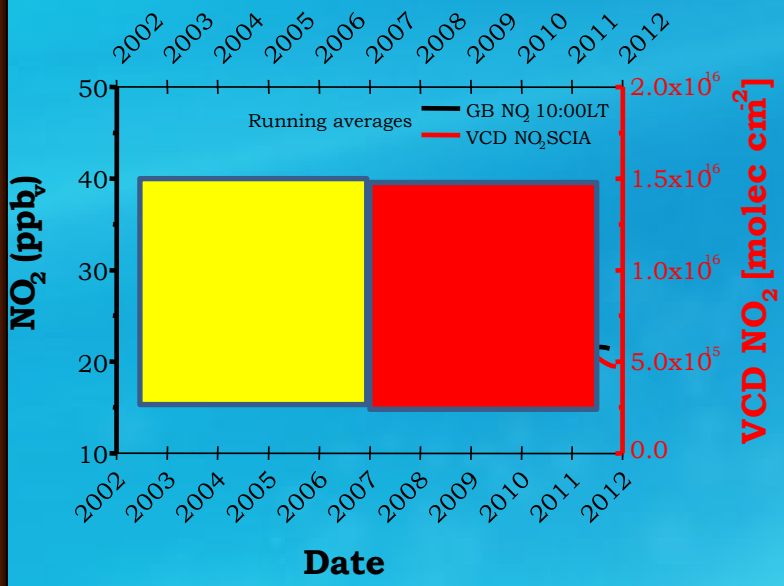


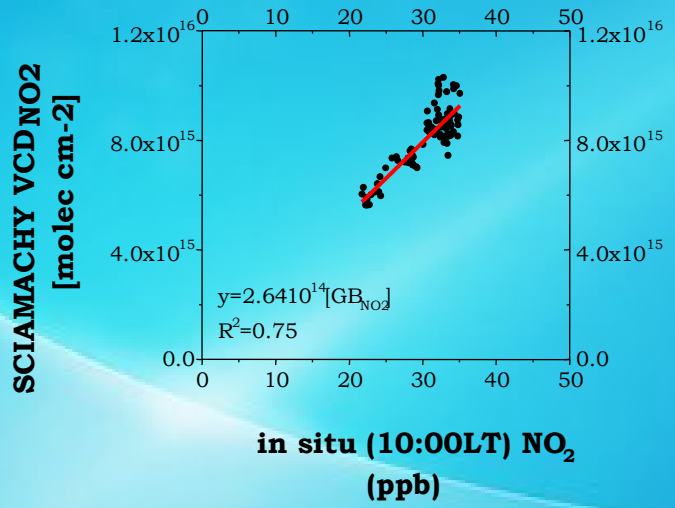
Source: Hellenic Statistical Authority (El-stat):
http://www.statistics.gr

Results (ground-based observations)

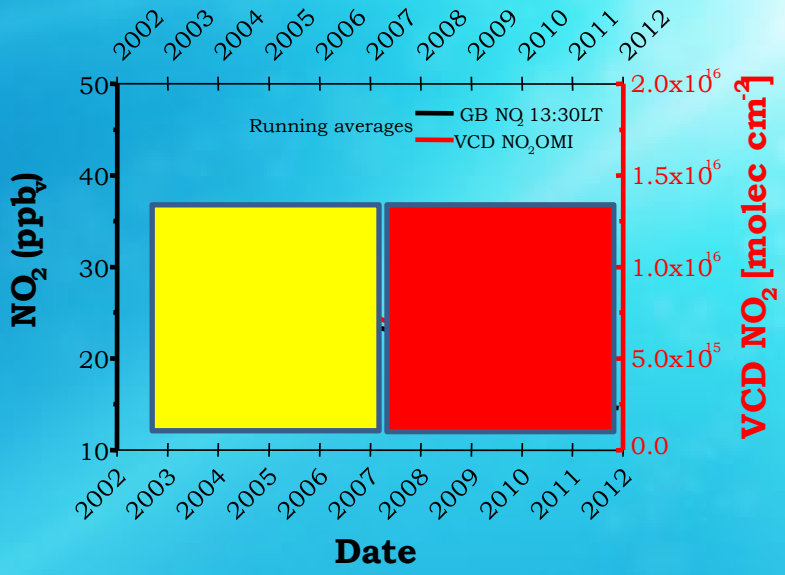
Comparison of satellite and in situ observations

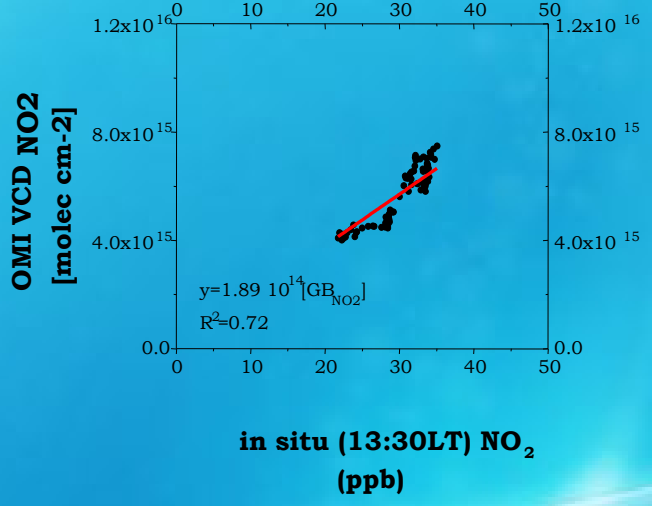
In situ NO_2 (10:00 LT) vs. SCIAMACHY VCD NO_2





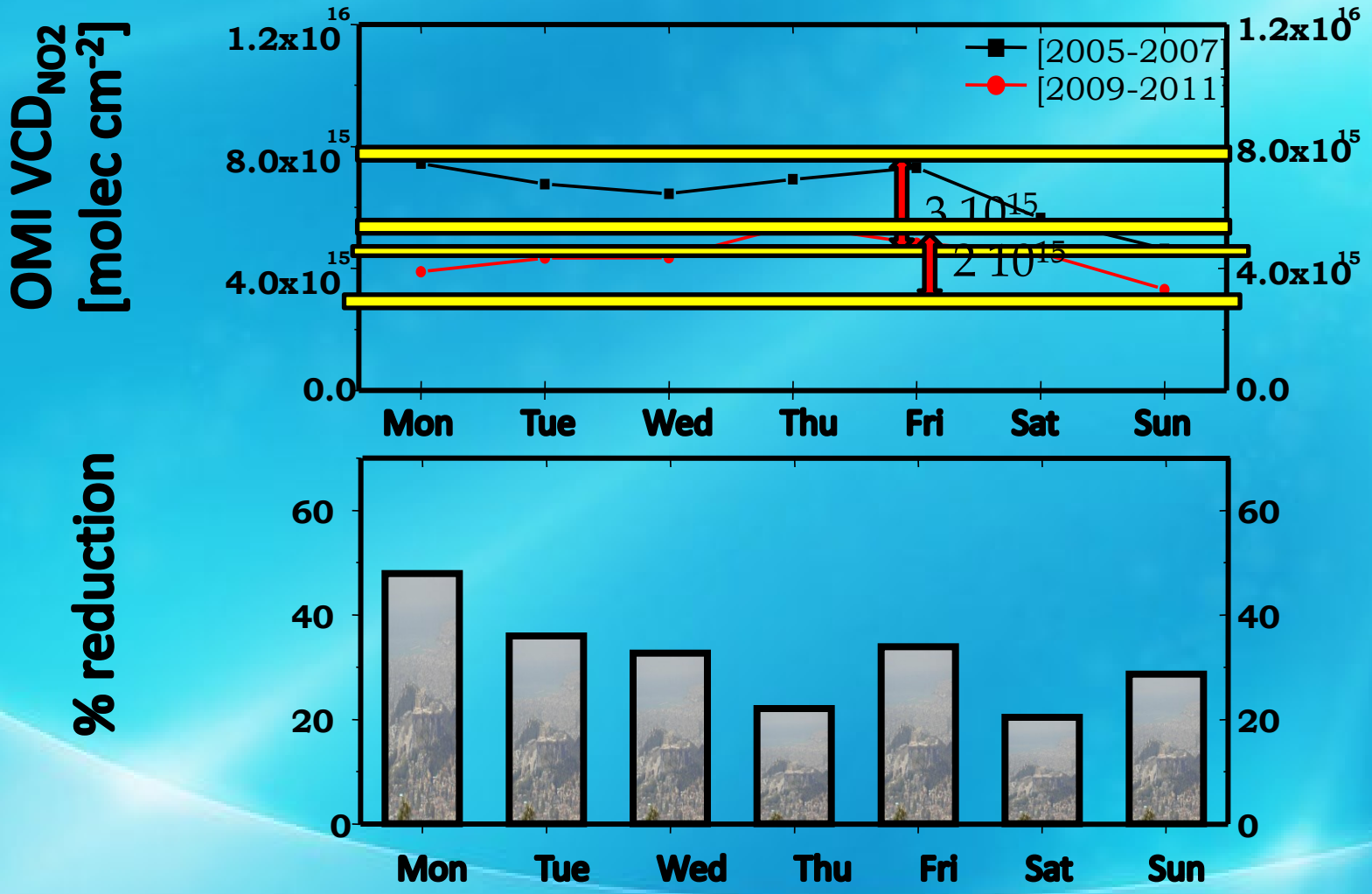
In situ NO_2 (13:30 LT) vs. OMI VCD NO_2





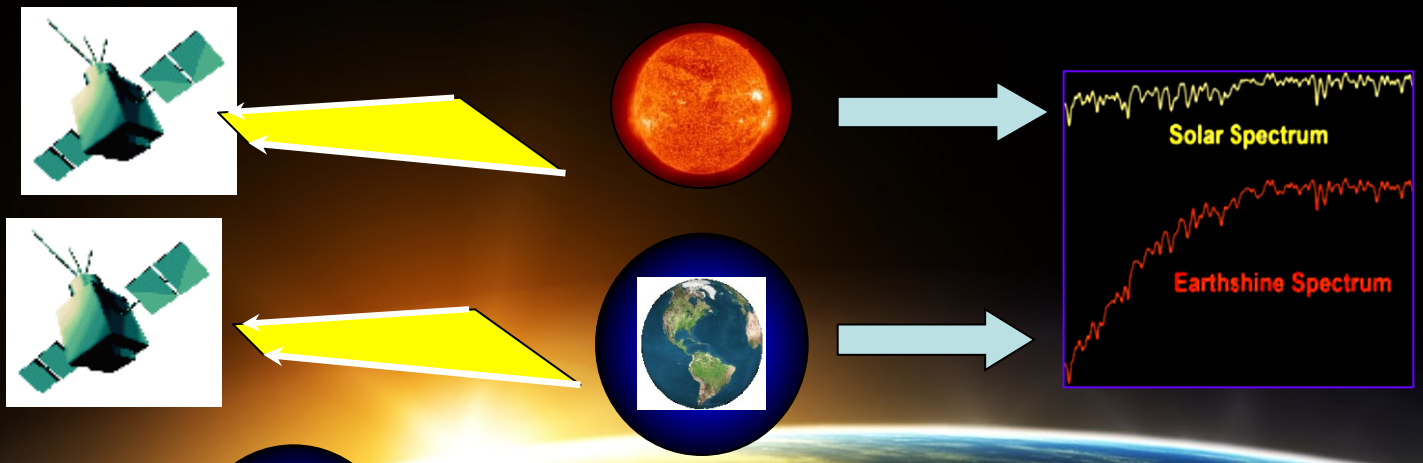
Results (satellite observations)

Weekend effect: VCD changes during economic recession



DOAS technique

Differential optical absorption spectroscopy



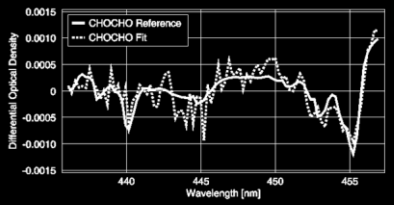
Solar irradiance, reference

Earthshine spectrum

$$\ln\left(\frac{\text{Earthshine}}{\text{Solar}}\right)$$

HCHO reference and fit

CHOCHO reference and fit



Lambert-Beer law

Fitting process

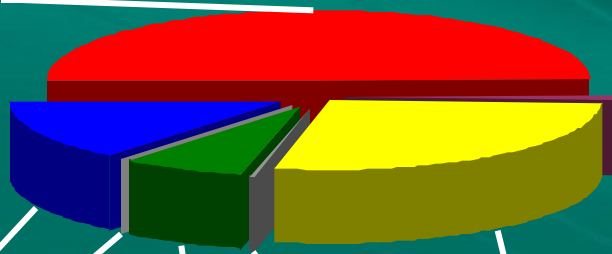
Species of interest

Sources of NOx in Tg N·y^{-1} (Troposphere)

Fossil fuel combustion

22

(51%)



Aircraft

0.5 (1%)

Soil emissions/NH_3 oxidation

6.0

(14%)

Oceans

0.1

Lightning

3.0 (6%)

Stratosphere

0.1

Biomass burning

11.6 (27%)

Wang et al, JGR, 1998