Satellite measurements of tropospheric trace gases in the CHARMEX project

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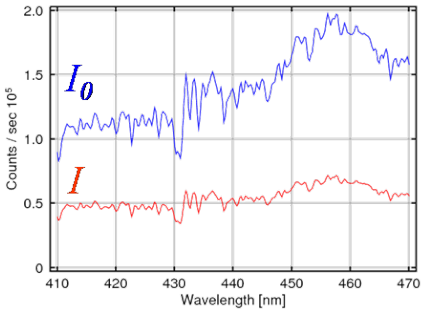
Outline

How and what do we measure?

The DOAS method

Differential **O**ptical **A**bsorption **S**pectroscopy – based on *Lambert Beer*:

$$\underbrace{ln\left(\frac{I_0(\lambda)}{I(\lambda)}\right)}_{\text{spectra}} = \underbrace{\int_s \sum_i \rho_i(s)\sigma'_i(\lambda,s)ds}_{\text{absorption term}} + \underbrace{\sum_k a_k \lambda^k}_{\text{polynomial}} + \underbrace{r(\lambda)}_{\text{residual}}$$



– trace gases
– ring effect

– broad-band effects

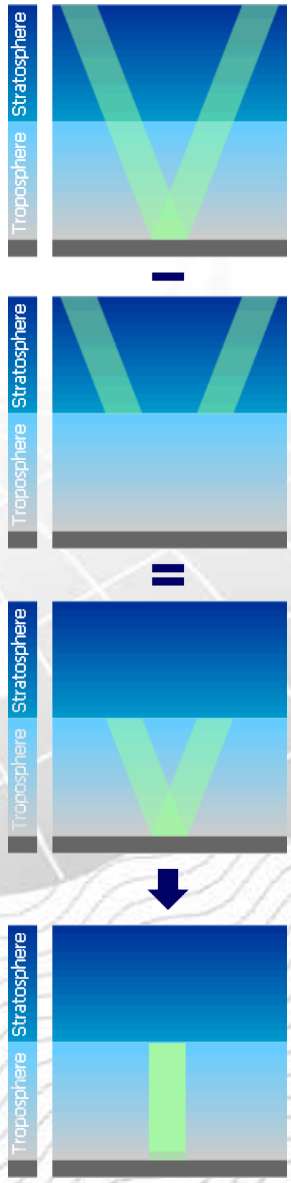
- $\sigma'_i + \sigma^b_i = \sigma_i$: differential + broad-band = total absorption
- Main inputs: I, I_0, the actual and background spectra from the instrument
  σ'_i, the reference absorption cross sections, measured in lab
- Main result: $SC_i = \int_S \rho_i(s)ds$, the *slant column* for each trace gas i

Deriving the tropospheric vertical column

- Measured quantity: *total slant column*
- Subtract influence of stratosphere (relevant for NO_2)
- Account for radiative transfer in the troposphere:

$$VCD_{trop} = SCD_{trop} / AMF \qquad \text{(AMF = Air Mass Factor)}$$

- Quantity of interest: *tropospheric vertical column*



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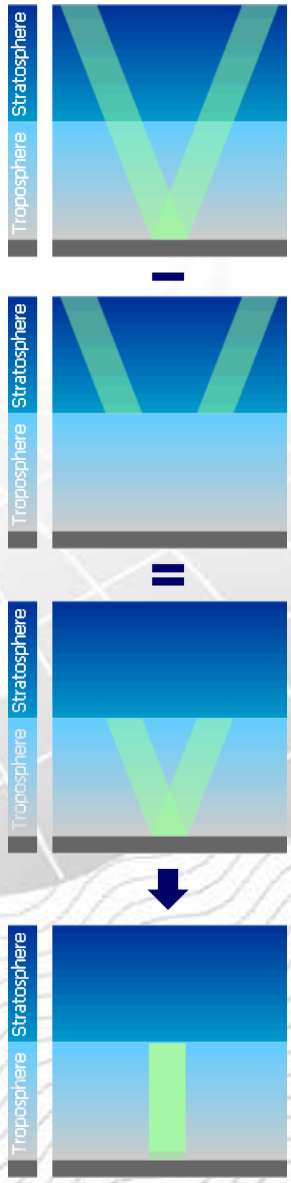


Radiative transfer in lower atmosphere depends on:

- Viewing geometry
- Vertical profiles of absorbers (derived from models)
- Ground reflectivity (measured from satellite)
- Surface height (measured from satellite)
- Aerosol load (derived from emission data)

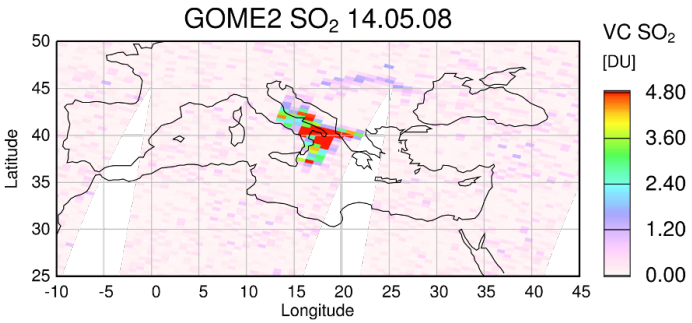
Satellite orbits / global coverage

- Sun-synchronous orbits $\Longrightarrow$ constant equator crossing time
- Important due to diurnal cycle in photochemistry
- North to south on day-side (except for OMI)

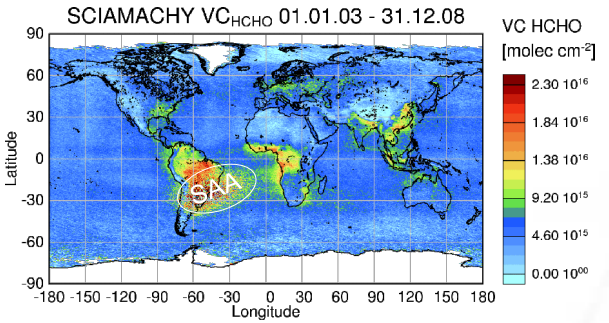
Instrument	**Equator crossing**	**Global coverage**	**Repeat cycle**	**Ground pixel [km^2]**
GOME	10:30	3 days	35 days	40x320
SCIAMACHY	10:00	6 days	35 days	30x60
OMI	13:45	1 day	16 days	up to 13x24
GOME-2	09:30	1.5 days	29 days	40x80

Animations from `http://www.esa.int/esa-mmg/mmg.pl?mission=MetOp&type=A`

Trace gases measured by UV/vis satellites

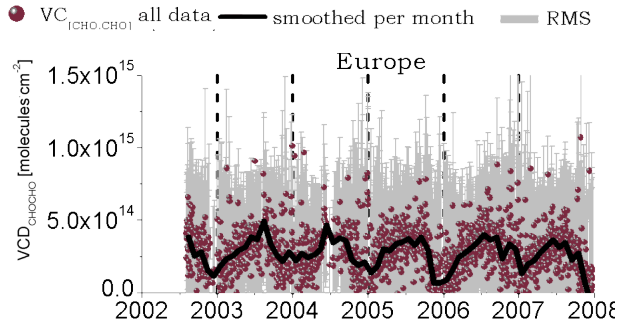


(c) Andreas Richter



(c) Mihalis Vrekoussis

Instrument	Mission duration	NO_2	SO_2	HCHO	CHOCHO	H_2O
GOME	1995/06-2003/06	+	+	+	-	+
SCIAMACHY	2002/08-*2013*	+	+	+	+	+
OMI	2004/10-	+	+	+	+	-
GOME-2	2007/01-*2015*	+	+	+	+	+



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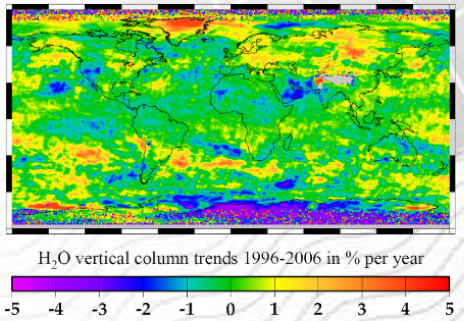
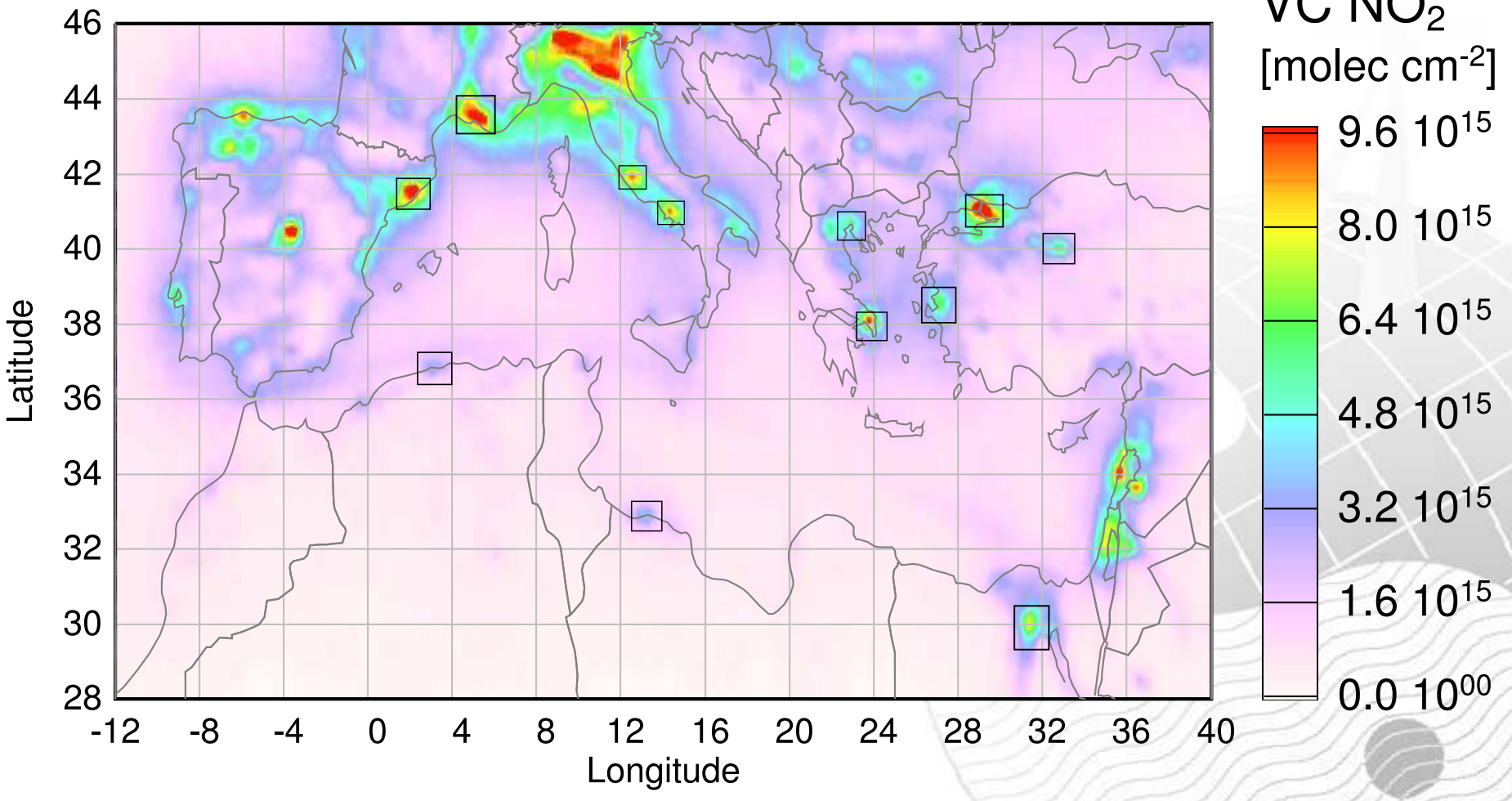


(c) Sebastian Mieruch

NO_2 over Megacities

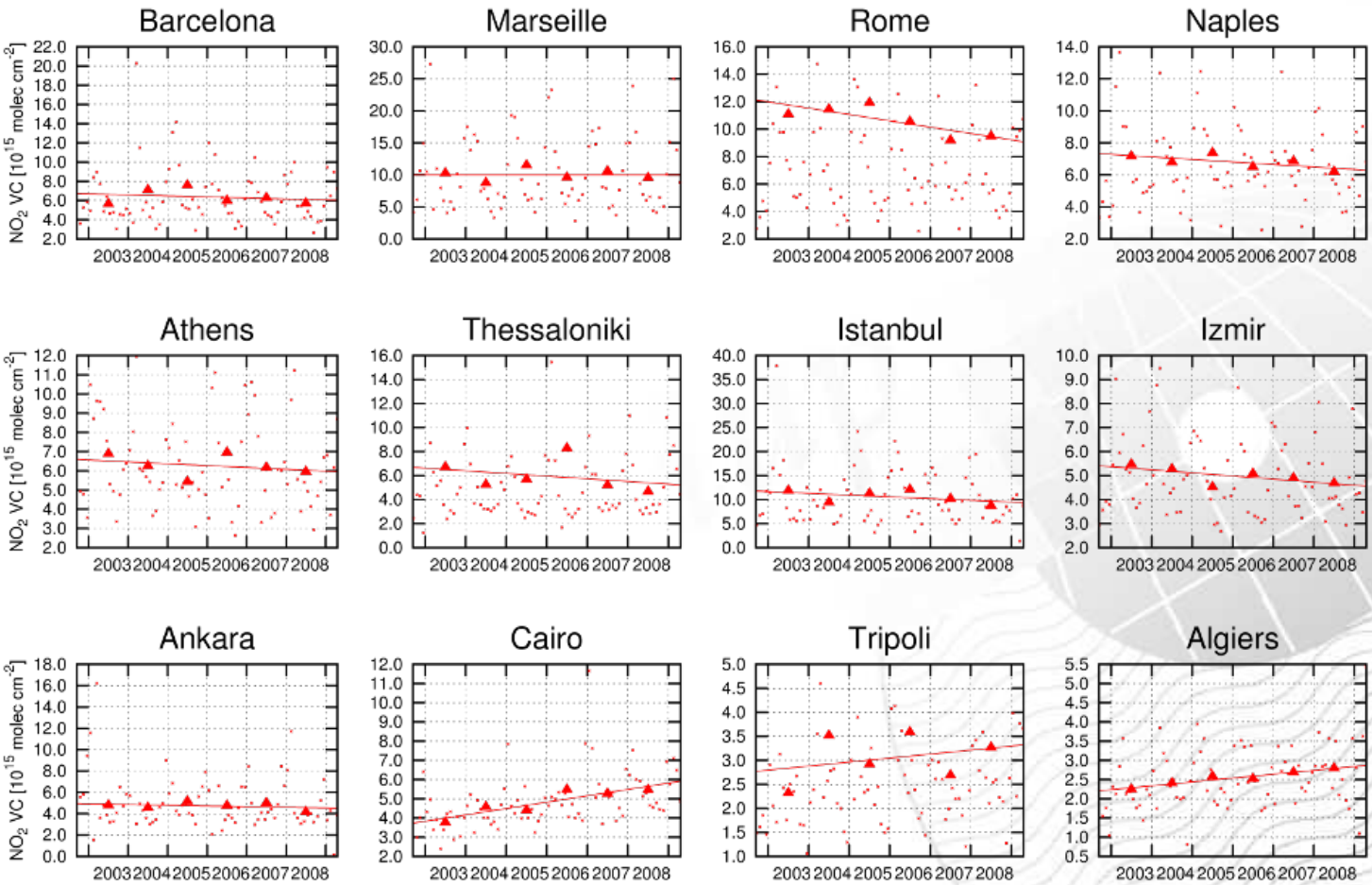
Tropospheric NO_2 in the Mediterranean

SCIAMACHY trop. NO_2 columns 2003-2008



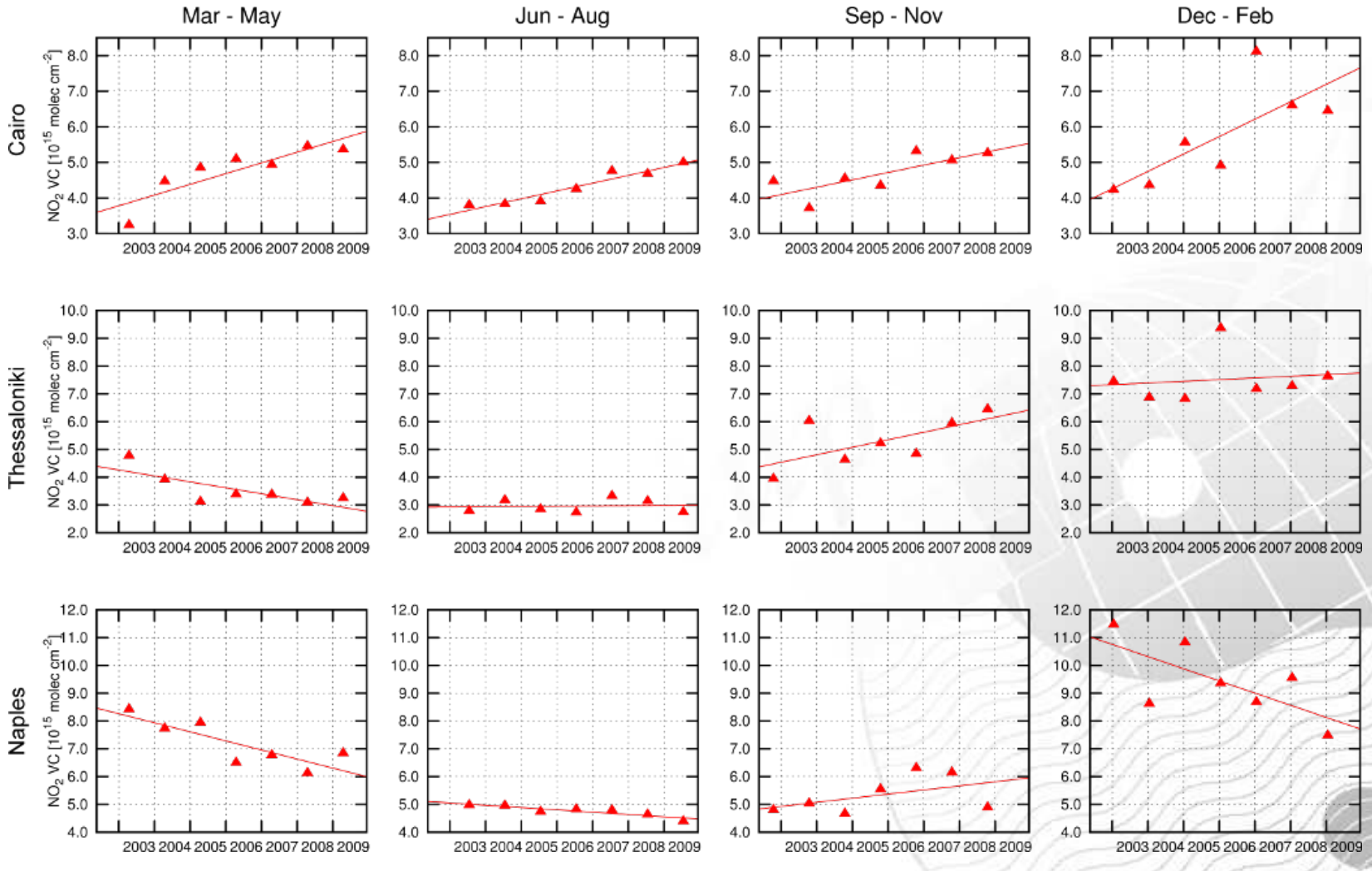
Trends in trop. NO_2 over Mediterranean megacities

Data from SCIAMACHY:
annual (▲) and monthly (·) means and linear fit to annual means (–)



Differing seasonal trends for the same city

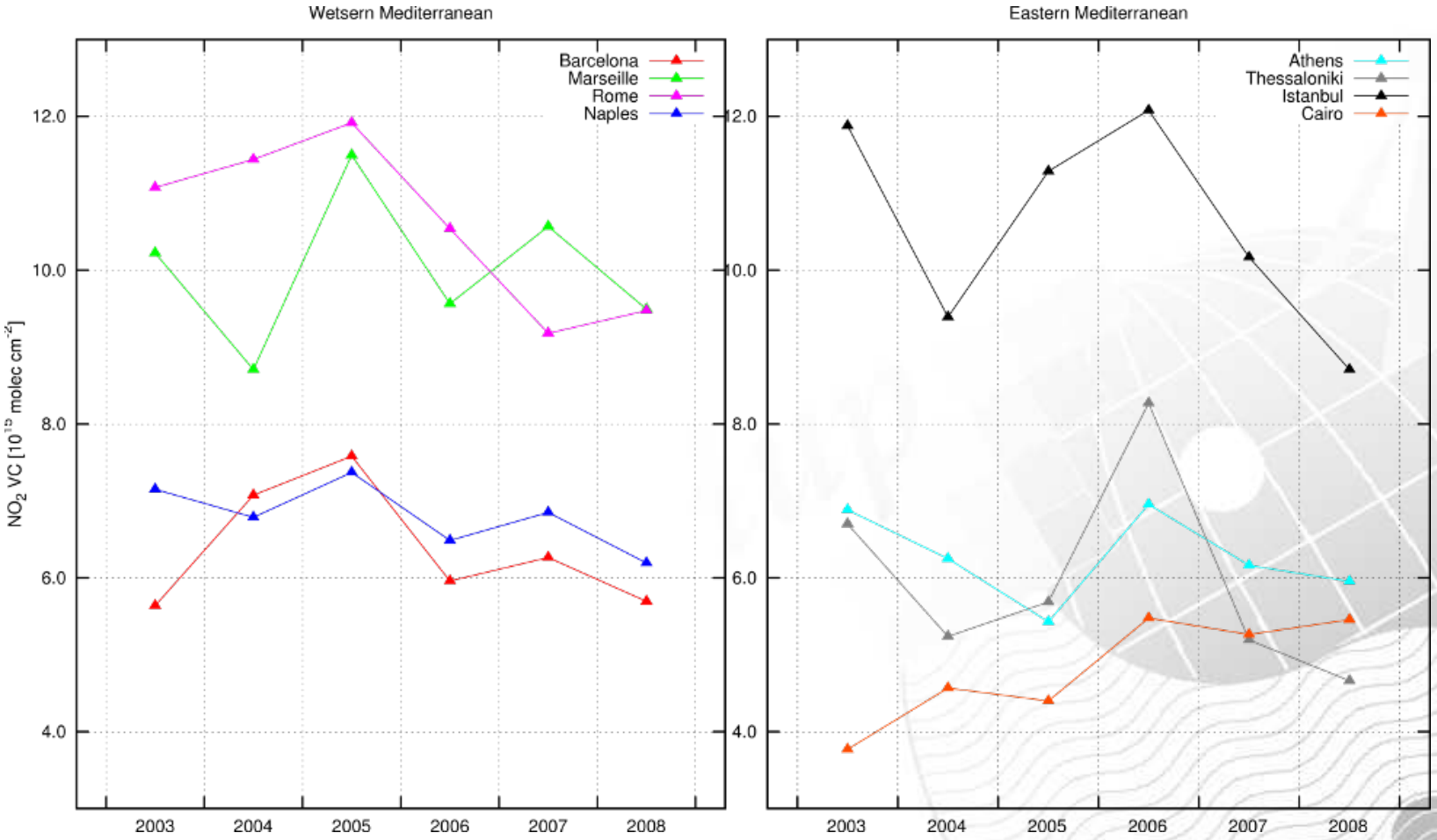
In some cities, trends have different signature depending on the season



SCIAMACHY seasonal means and their linear fit

Difference Western vs. Eastern Mediterranean

Eastern and western Meditteranean show different patterns



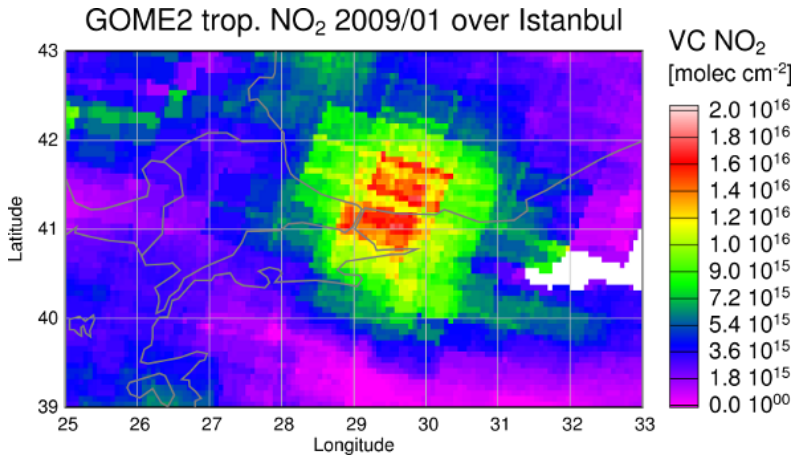
SCIAMACHY annual means

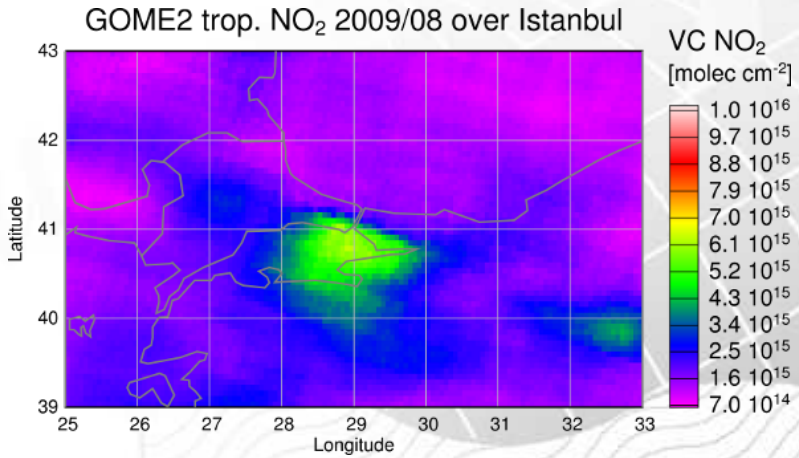
Seasonal differences in NO_2 over Istanbul

Depending on season, Istanbul's NO_2 plume can be seen

- north (winter)
- south (summer)

of the Bosphorus.





- Study correlation between wind directions and NO_2 plume location

Future Studies

Extension of time series

GOME data available since August 1995 — so why don't I show trends for the 1995-2009 time period?

- Coarser pixel size leads to lower values over hot spots
- Derivation of consistent trends difficult

Solution: Deconvolution of GOME measurements

- Superimpose finer structure of SCIAMACHY measurements upon coarser GOME pixels

  (See *Konovalov et al., 2006)*

High-resolution study of Istanbul

CHARMEX aim *Trends due to changes in local emissions*

Emissions inventory with 2km resolution makes model run (CHIMERE?) with very fine gridsize possible

- High-resolution AMF leads to high quality / high resolution satellite data product
- Study the influence of the city on its surroundings and vice/versa
- Problem: Currently no annual emission data

Summary

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- High-quality global time-series (2003-2009) available for NO_2, SO_2, HCHO, CHOCHO & H_2O
- Time-series for NO_2 will be extended to cover GOME period (starting 1996)
- Most western megacities show decreasing NO_2 values
- Most non-european megacities show increasing NO_2 values
- Eastern and western Mediterranean cities show different patterns in annual NO_2 values
- Location of a megacity's NO_2 plume can vary drastically with season

Acknowledgements

- DOAS group at IUP / Uni-HB (`http://doas-bremen.de`)
  - Andreas Richter
  - Mihalis Vrekoussis
- ESSReS Graduate School (`http://earth-system-science.org`)
- European FP7-project CityZen (`http://wiki.met.no/cityzen/`)

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Merci beaucoup pour votre attention