University of Bremen Institue of Environmental Physics

Trends in tropospheric nitrogen dioxide (NO_2) over megacities in the Mediterranean and Middle East from GOME and SCIAMACHY

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Outline

Introduction

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- Megacities: pollution hot spots due to high energy use
- NO_2: ozone smog, acid rain, hazardous to human health
- Satellite instruments: long timeseries, global coverage

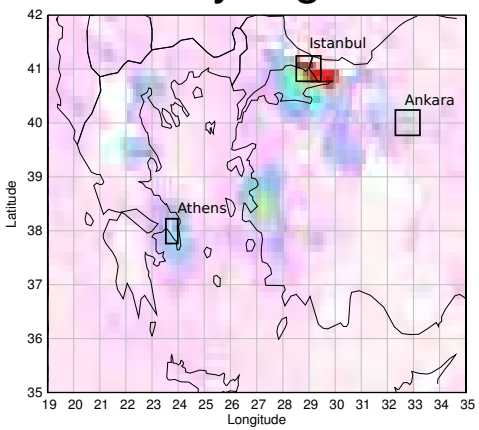
Instrument	**Equator crossing**	**Global coverage**	**Available period**	**Pixel [km^2]**
GOME	10h30	3 days	1995/10-2003/06	40 × 320
SCIAMACHY	10h00	6 days	2002/08-now	30 × 60

- **D**ifferential **O**ptical **A**bsorption **S**pectroscopy (*Lambert-Beer*)
- Subtraction of stratospheric NO_2 from scaled model data
- Correction for average lightpath in atmosphere
- **Vertical tropospheric column [molec. cm^{-2}] NO_2**

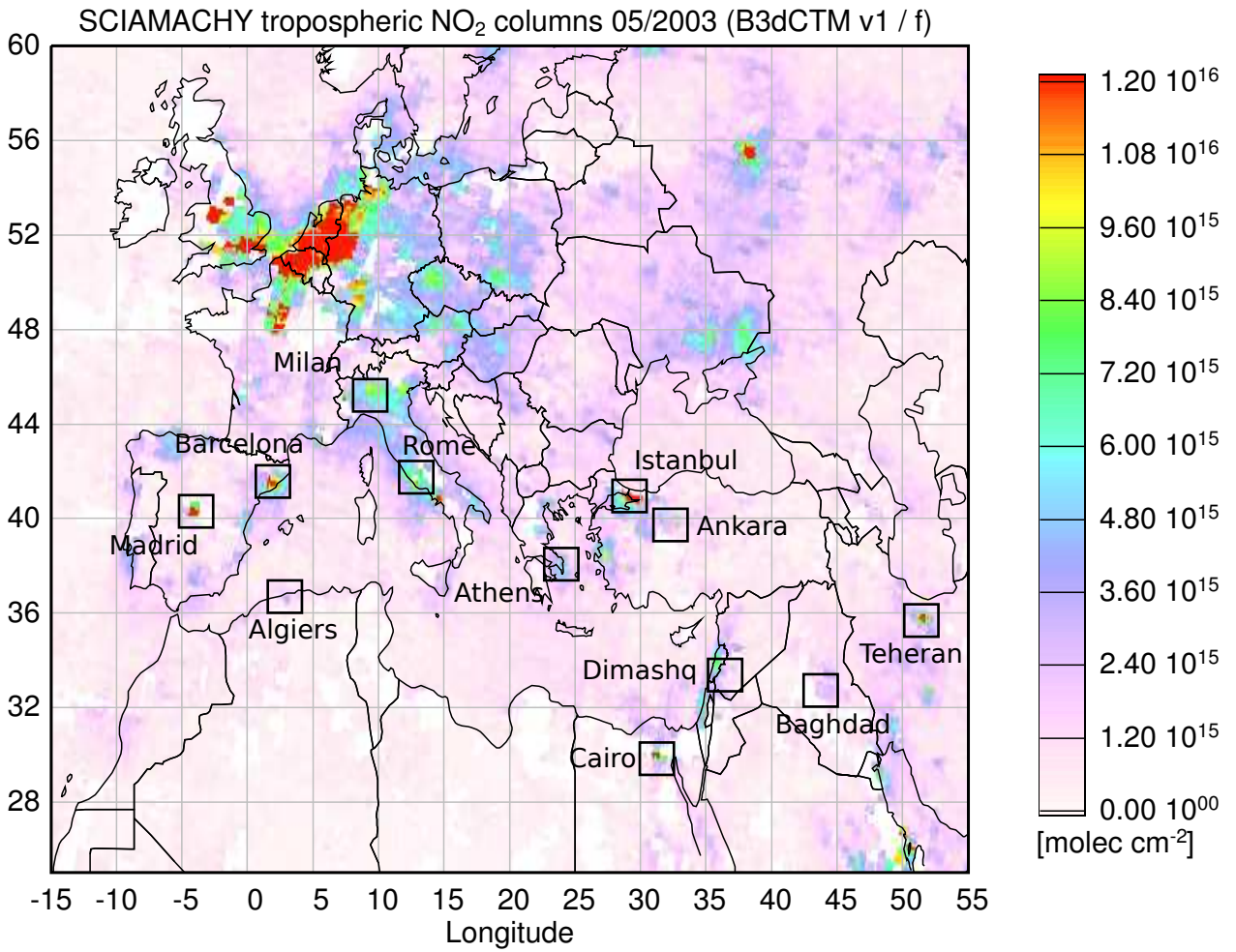
The GOME/SCIAMACHY timeseries

Overview

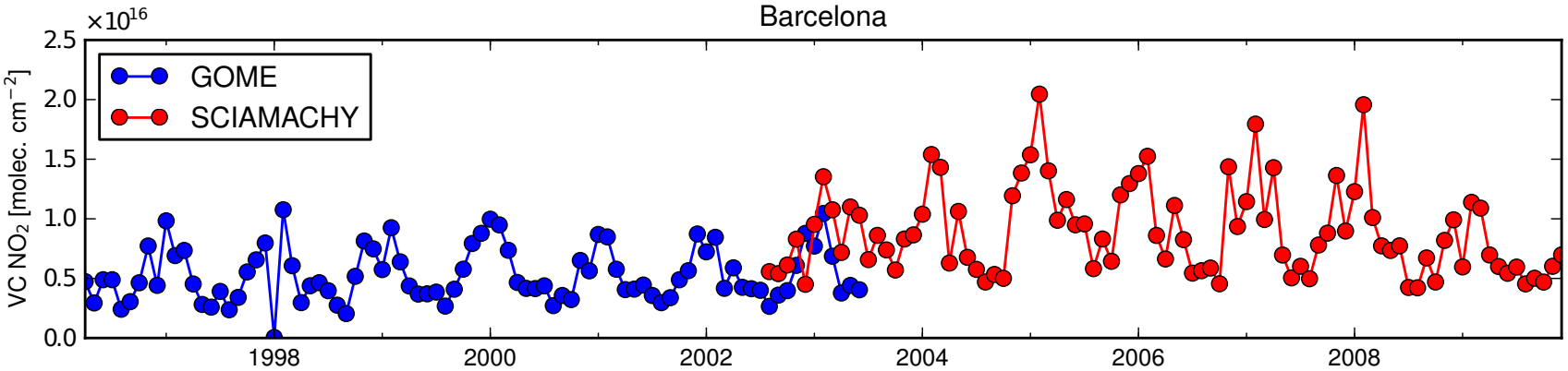
- Grid satellite pixels on $0.125° \times 0.125°$
- Calculate monthly averages
- Define city regions

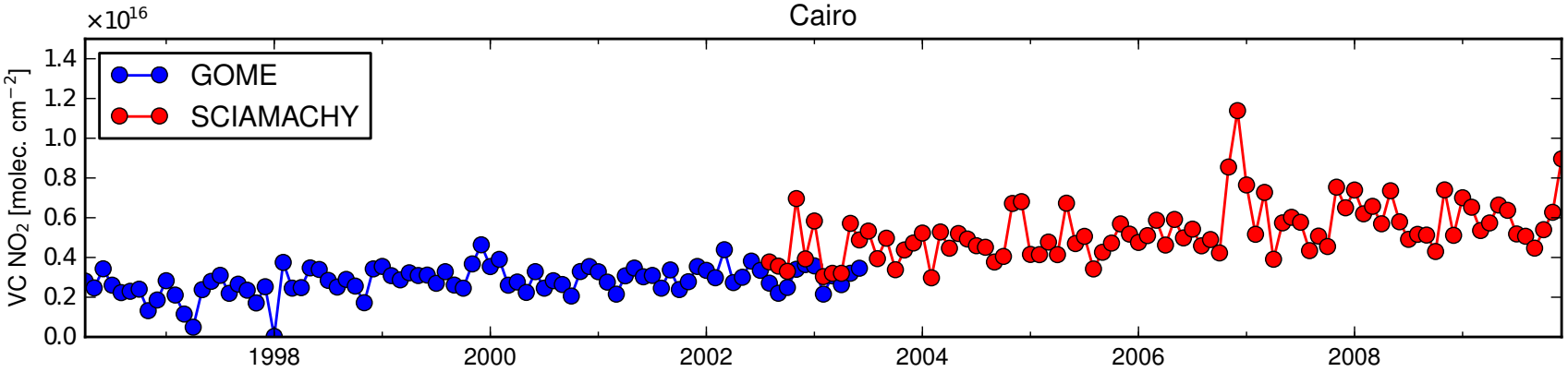


- For each month, calculate the average of each city region individually



Combined GOME/SCIAMACHY timeseries





- Most investigated cities show upward tendencies
- Clear gap between the GOME and SCIAMACHY timeseries
- **Quantitative estimation of trends not feasible!**

Constructing one consistent timeseries from GOME and SCIAMACHY

The problem of differing pixel sizes

- GOME and SCIAMACHY have very different spatial resolution:

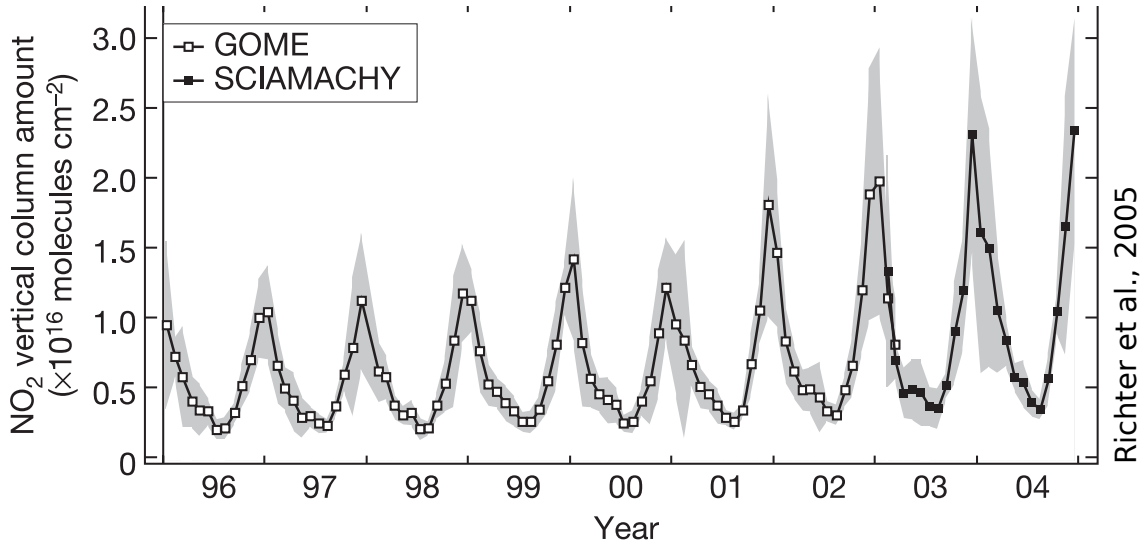
SCIAMACHY: 60 x 30 km^2, 16 pixels per swath

GOME: 320 x 40 km^2, 3 pixels per swath

The problem of differing pixel sizes

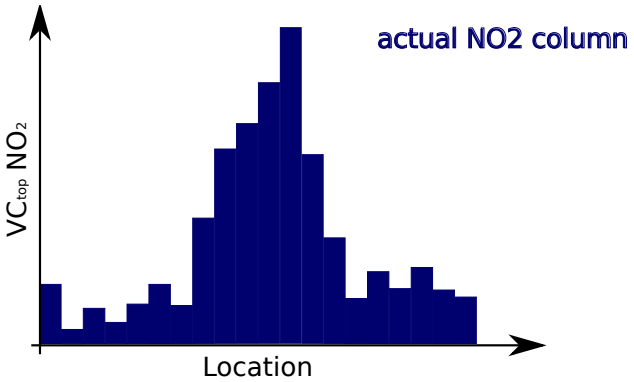
- GOME and SCIAMACHY have very different spatial resolution:
- For averages over large areas, this is no big problem:

Monthly averages of NO_2 VC_{trop} over East Central China



The problem of differing pixel sizes

- GOME and SCIAMACHY have very different spatial resolution:
- For averages over large areas, this is no big problem:
- For very localized sources (like cities), this leads to a relatively diluted signal in the GOME data — the same total amount of NO_2 is averaged over a larger area:



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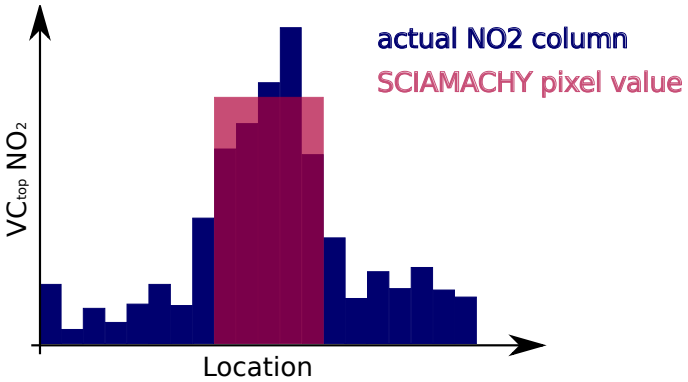

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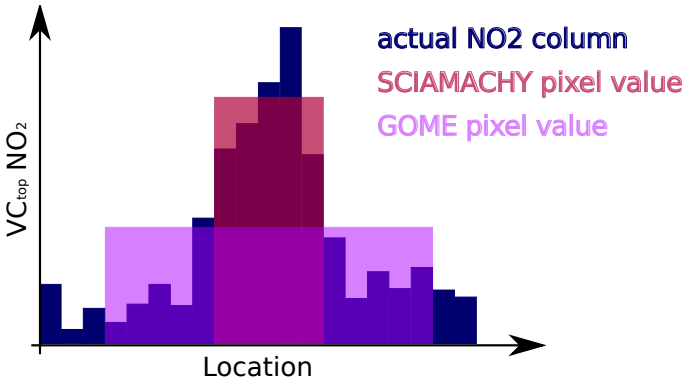

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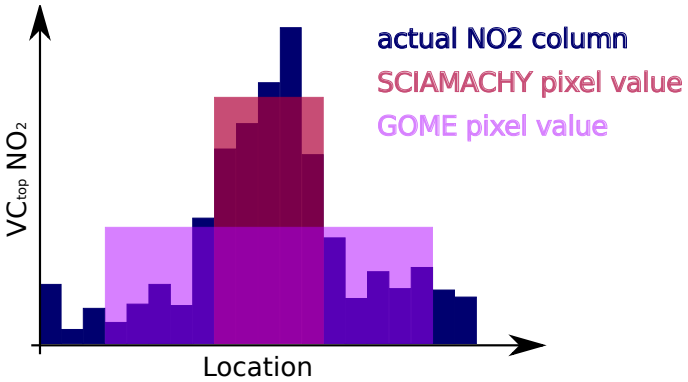
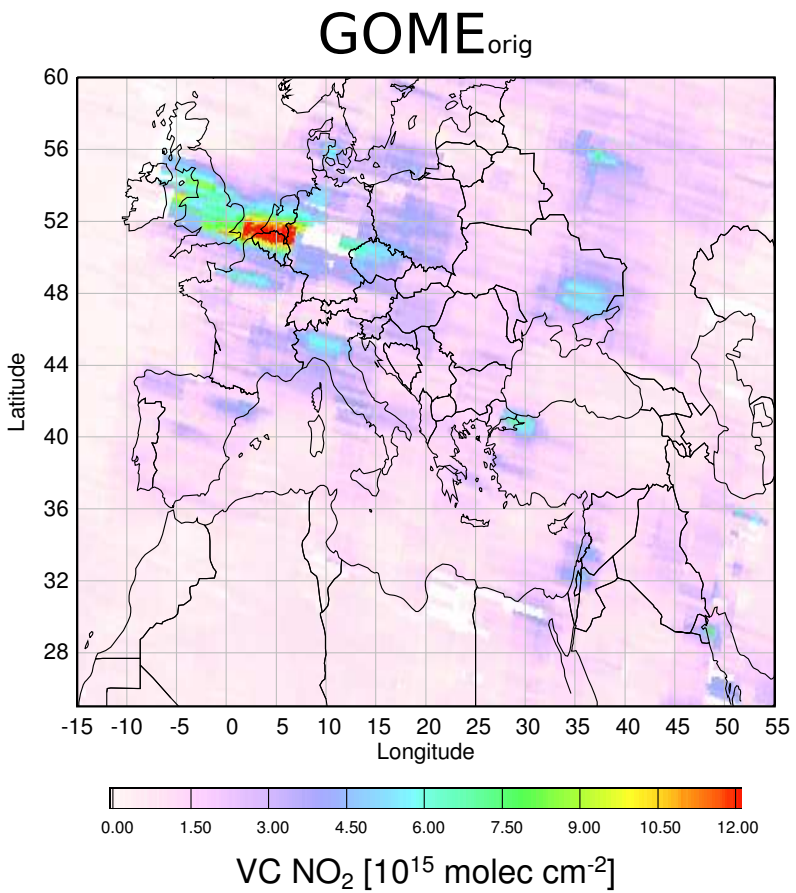
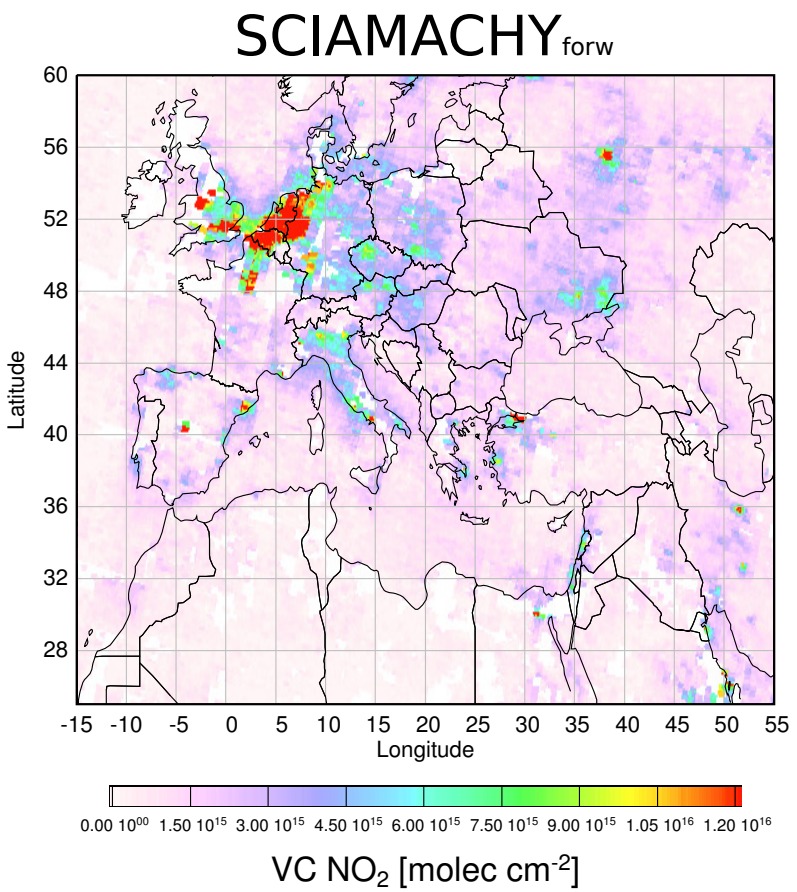


- This leads to inconsistencies in timeseries spanning both GOME and SCIAMACHY.
- **Any trend study of megacities needs to consider this effect**

Comparison: GOME and SCIAMACHY measurements

Average tropospheric NO_2 columns May 2003:





What to do about this?

Previous studies artificially reduced resolution of SCIAMACHY measurements:

Publication	*Time period covered*
van der A et al., 2008	1996-2006
Konovalov et al., 2010	1996-2008

or calculated a correction factor for GOME measurements by convolving SCIAMACHY measurements (Konovalov et al., 2006)

Derived annual trends:

City	*van der A.*	*Konovalov (2010)*
Baghdad	—	1.7 ± 0.7 %
Barcelona	—	3.7 ± 0.8 %
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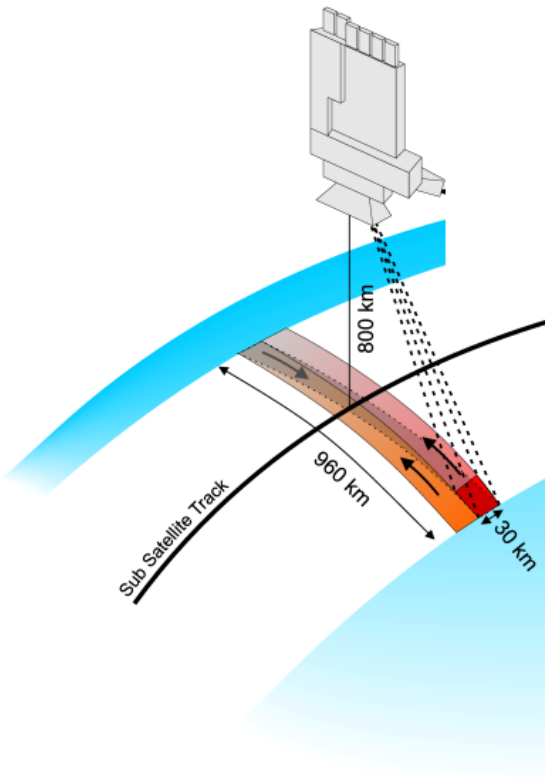
The simplest approach:

average 5 neighboring SCIAMACHY pixels. But:

- non-linearities in the retrieval
- what to do with clouds
- ...

Making use of SCIAMACHY backscan measurements



- SCIAMACHY scans 16 pixels 60x30km per forward scan
- 4 pixels 240x30km per backward scan
- backscan pixels close in size to GOME pixels
- backscan “does” the same to ground scene as GOME

Impose the spatial structure of SCIAMACHY measurements on GOME data:

- monthly maps of SCIAMACHY back and forward scan measurements
- monthly maps of $SCIA_{forw}$ / $SCIA_{back}$
- monthly climatology of $SCIA_{forw}$ / $SCIA_{back}$
- monthly maps of GOME measurements
- monthly maps of GOME $\times$ $SCIA_{forw}$ / $SCIA_{back}$

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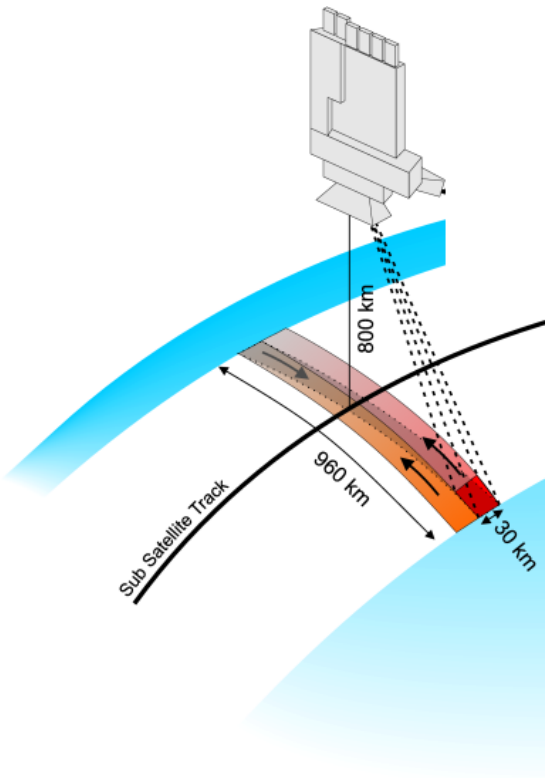

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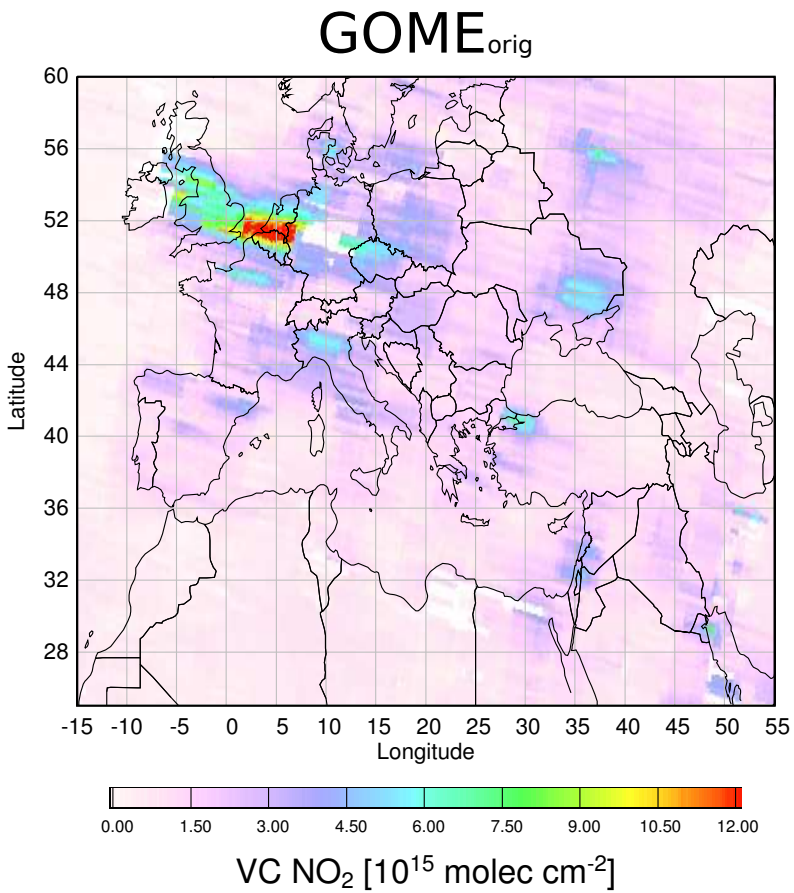
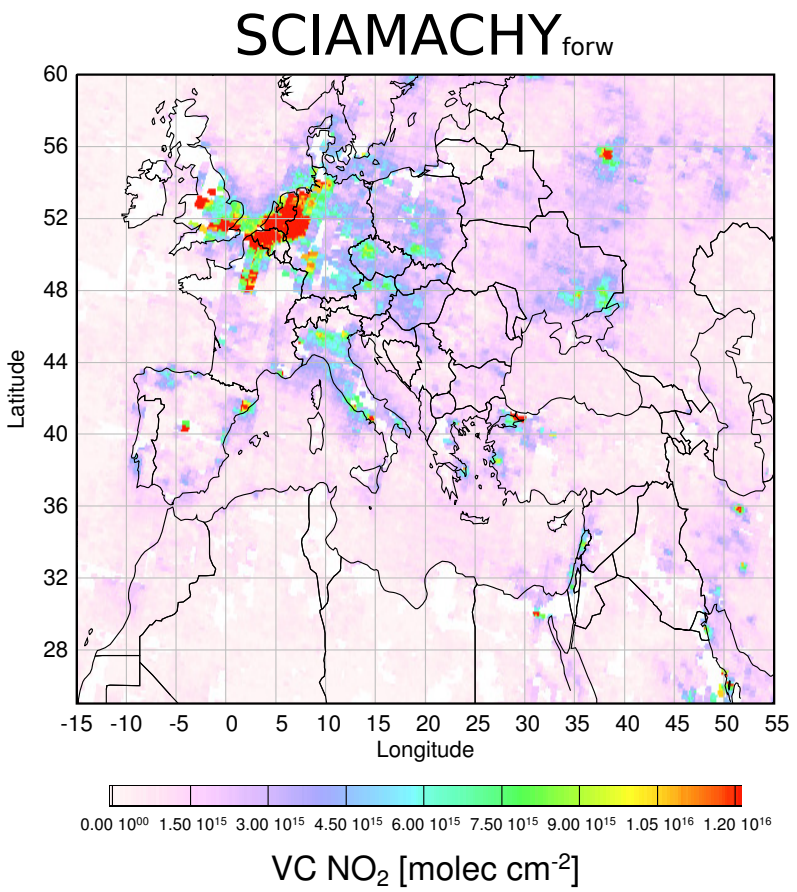
The impact of the SCIAMACHY back scan method

Average tropospheric NO_2 columns May 2003:





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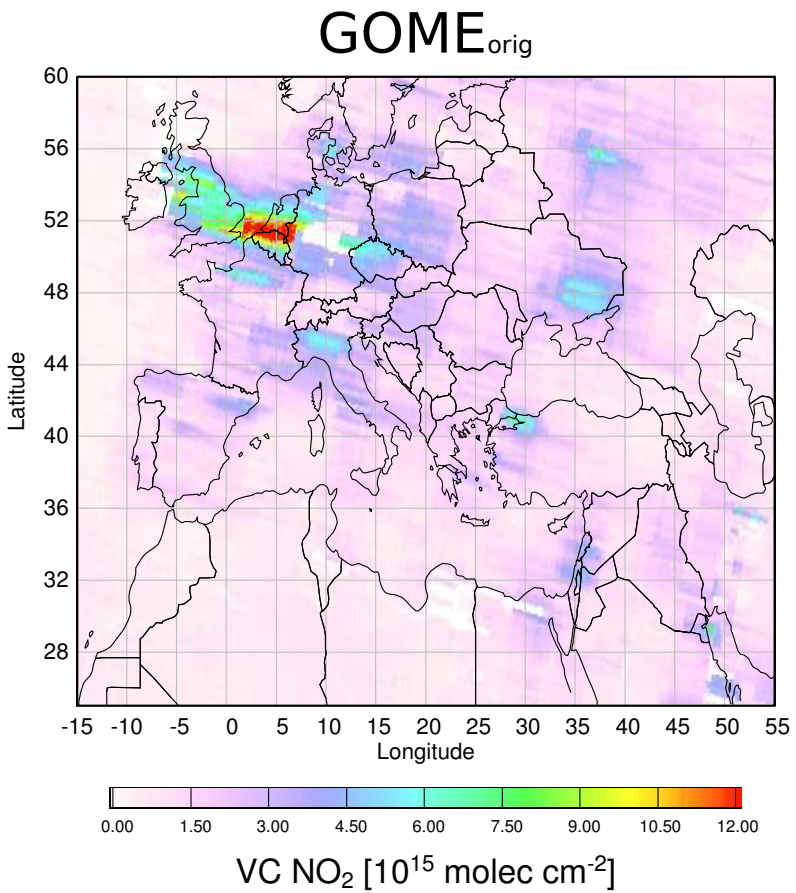

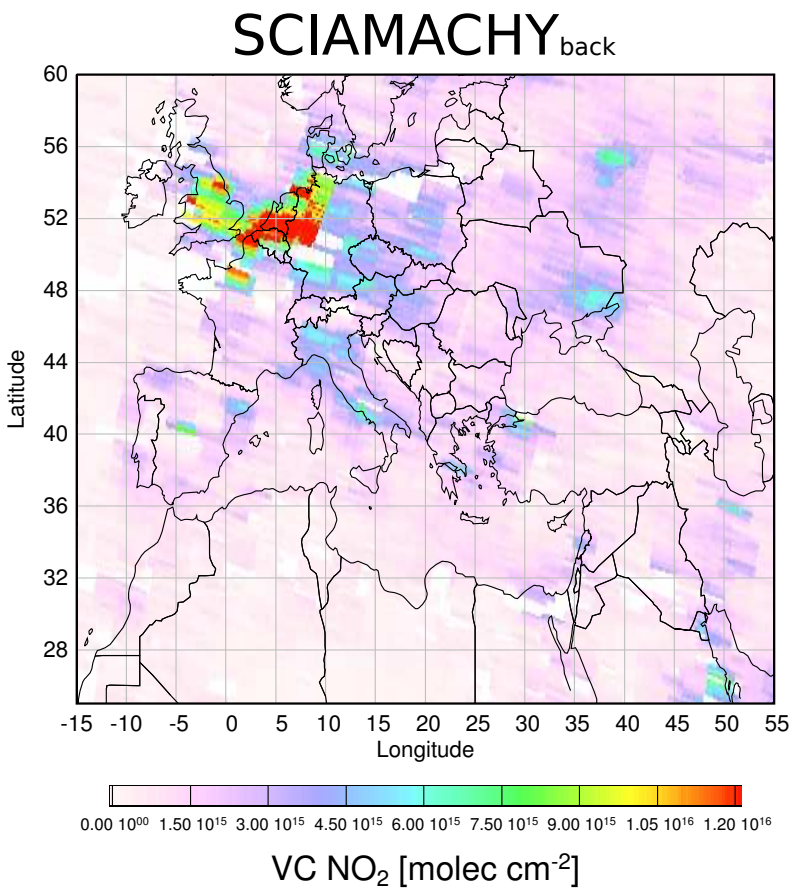

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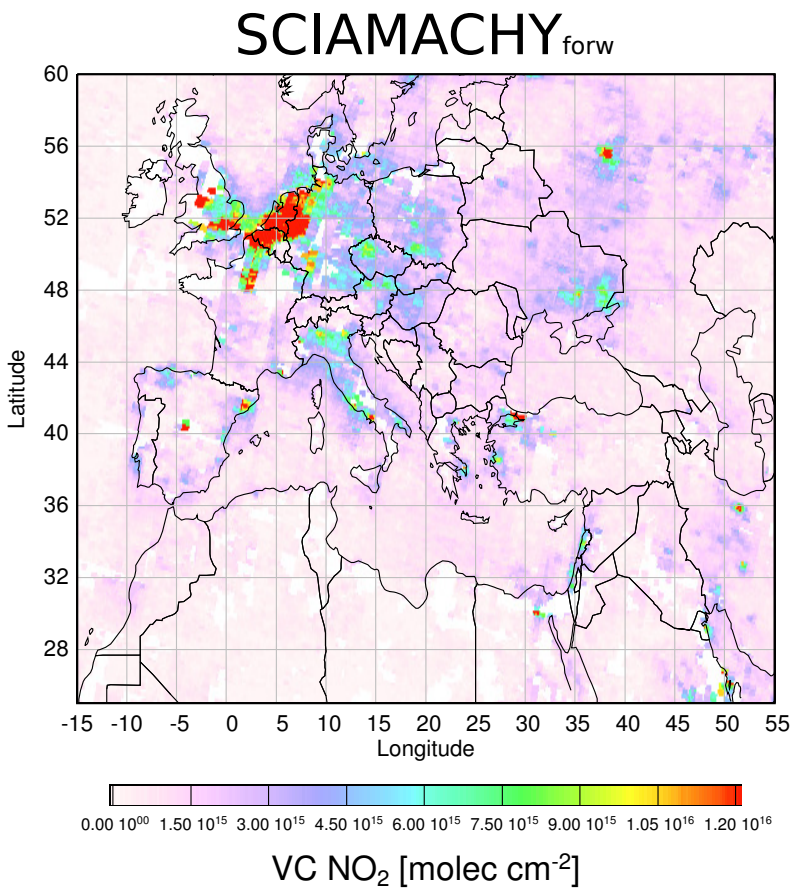

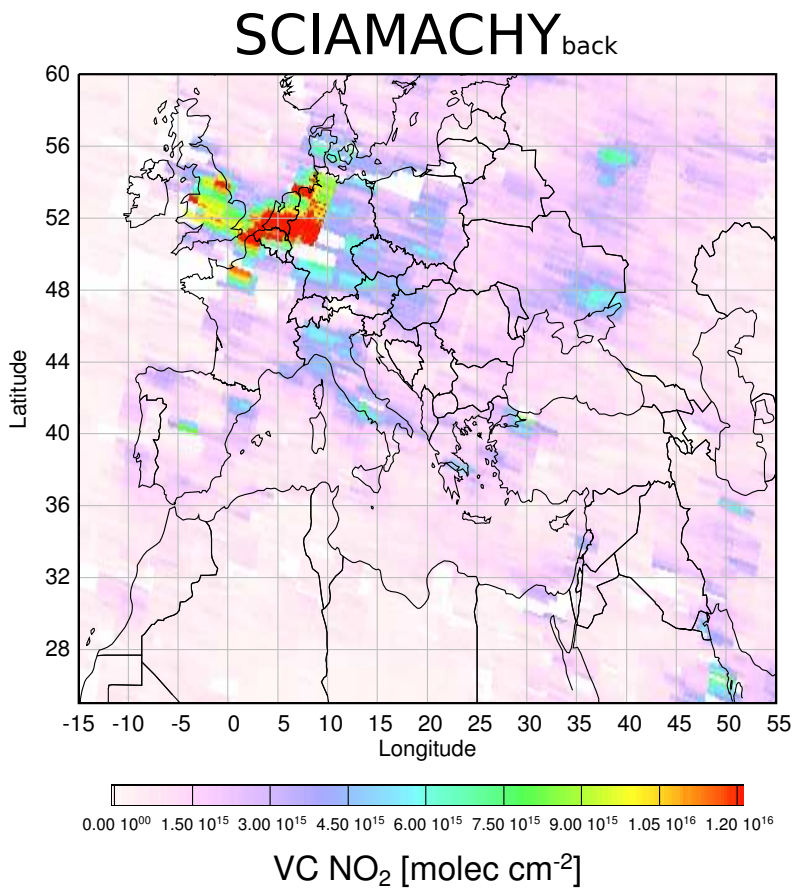

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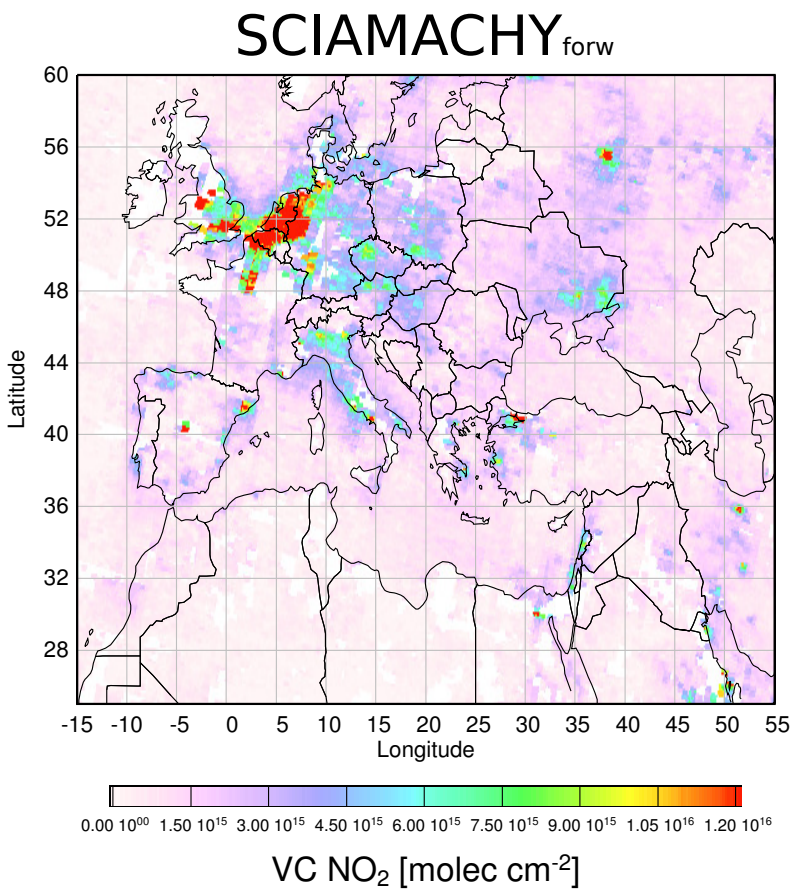
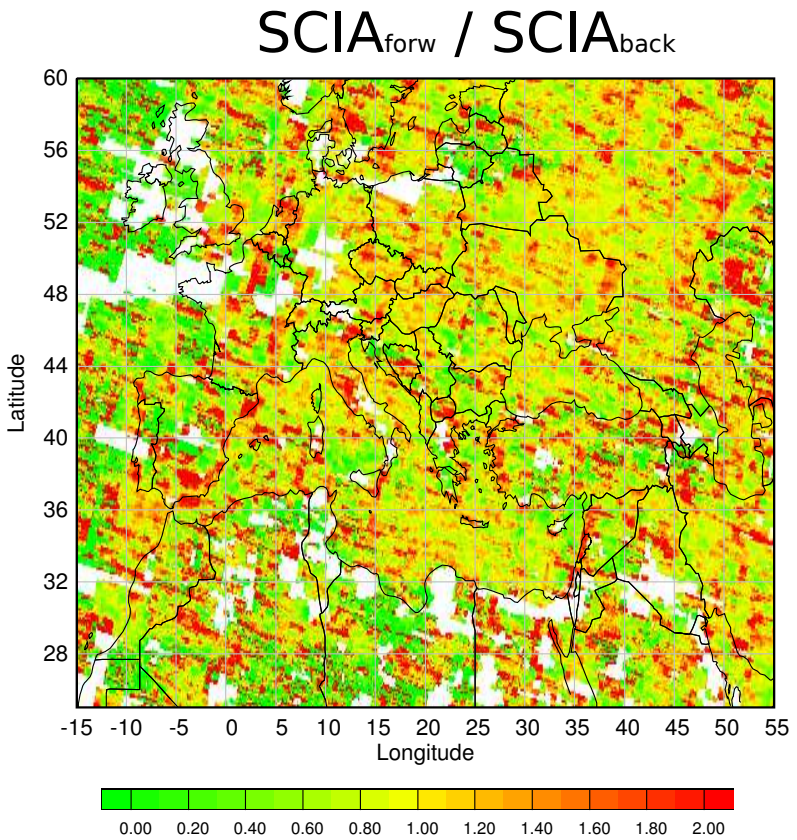
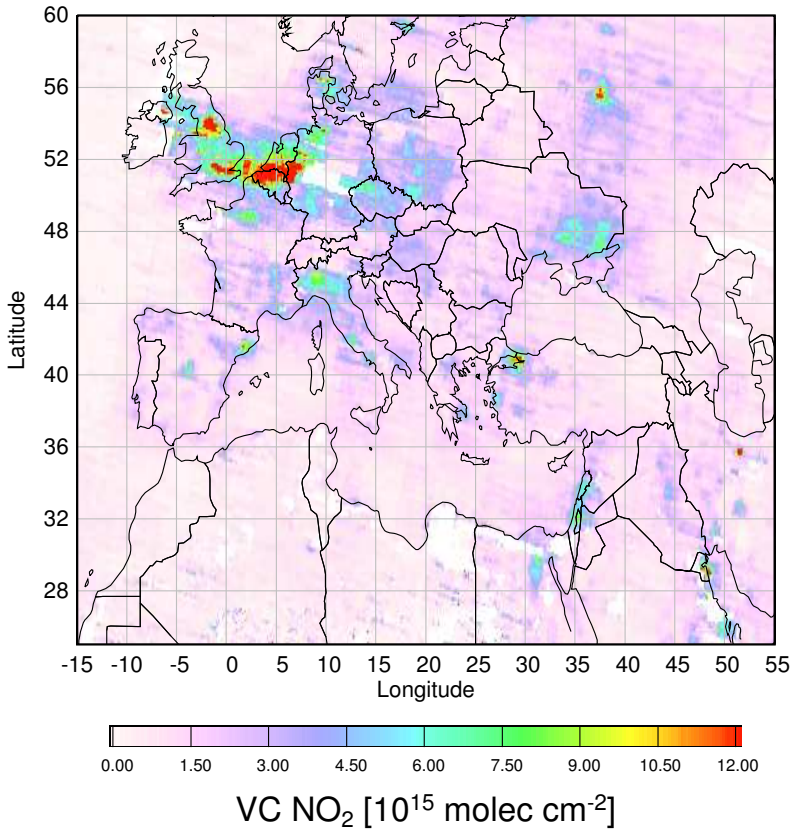




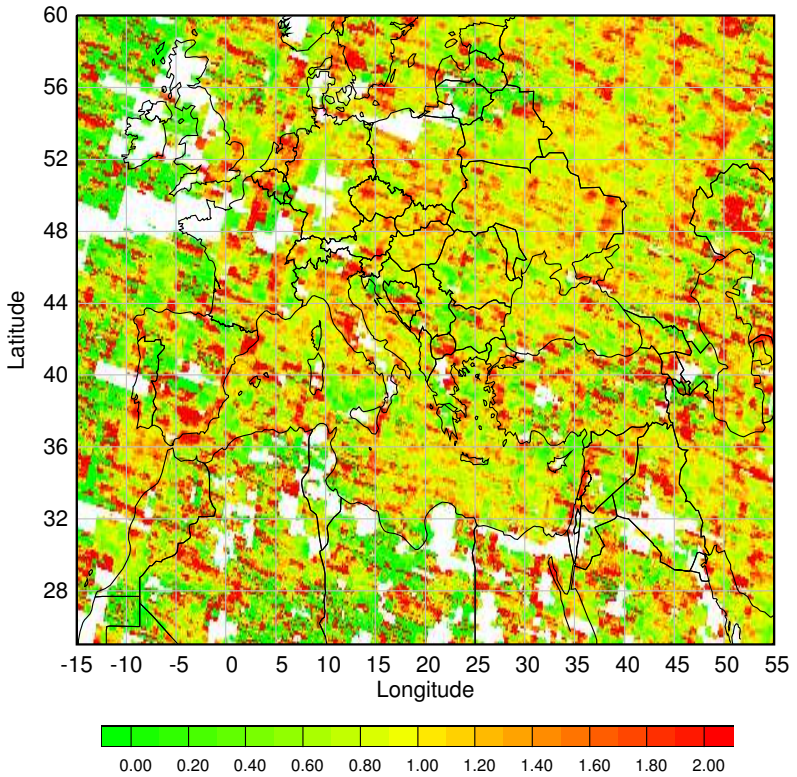
The impact of the SCIAMACHY back scan method

Average tropospheric NO_2 columns May 2003:

GOME x ($SCIA_{forw}$ / $SCIA_{back}$)



$SCIA_{forw}$ / $SCIA_{back}$



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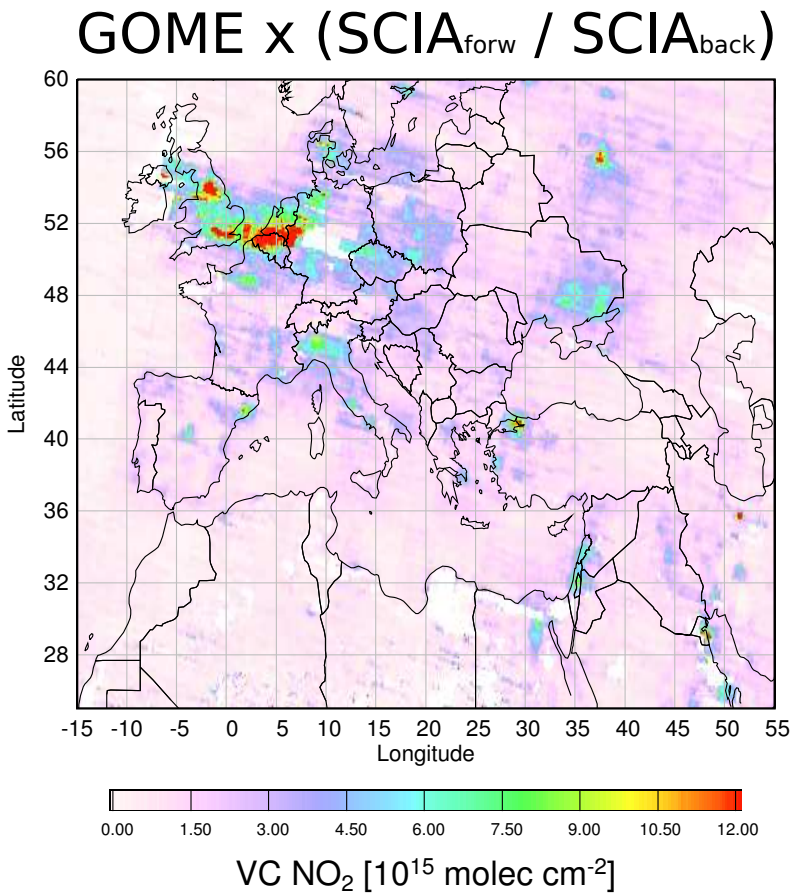
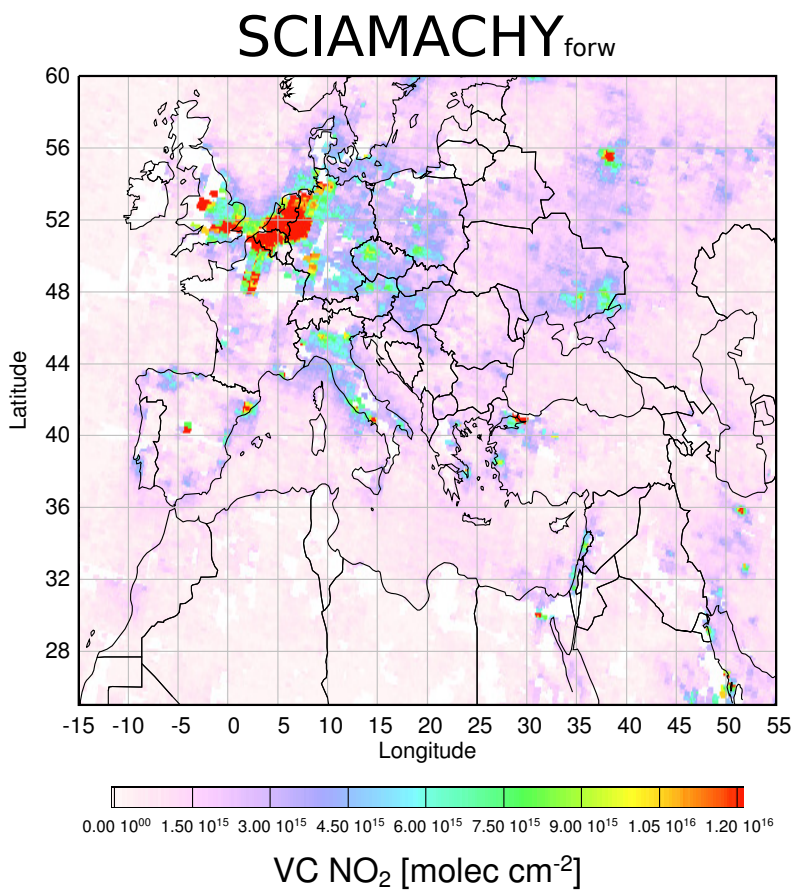
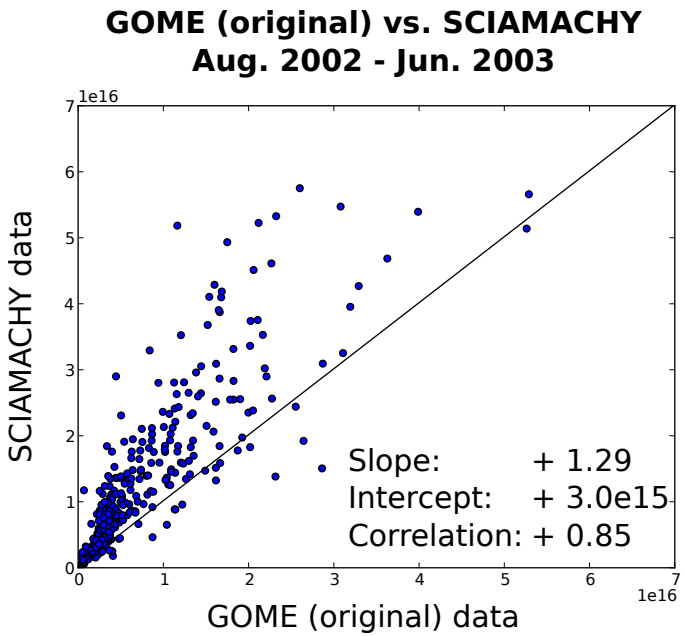
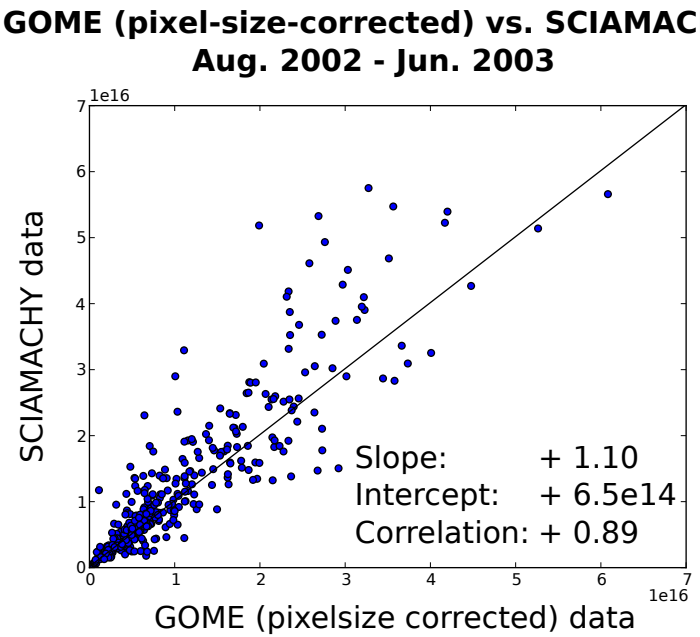




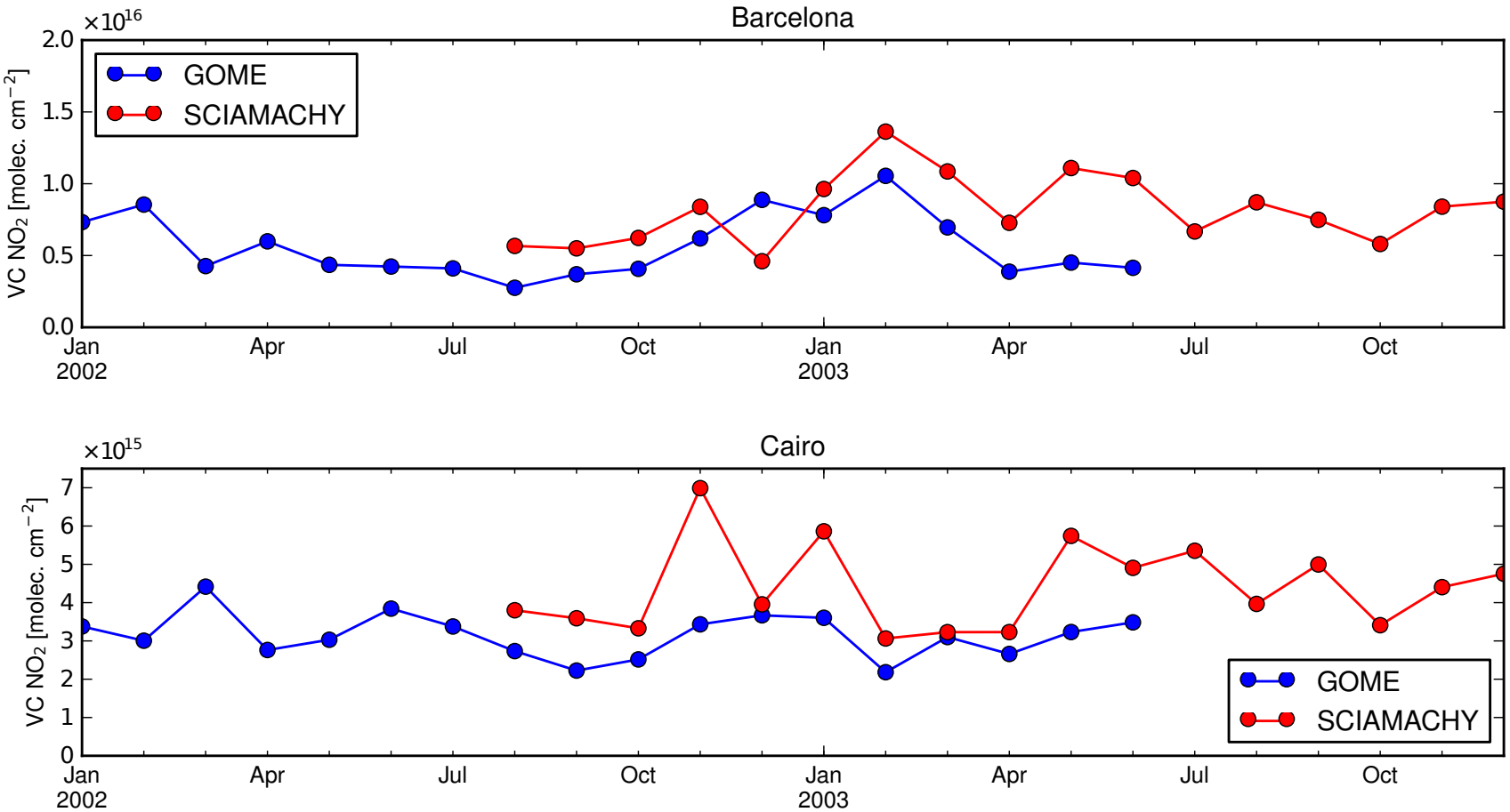
Comparison corrected / original dataset

Correlation between monthly mean values of GOME and SCIAMACHY measurements over 33 megacities





Combined timeseries from GOME and SCIAMACHY



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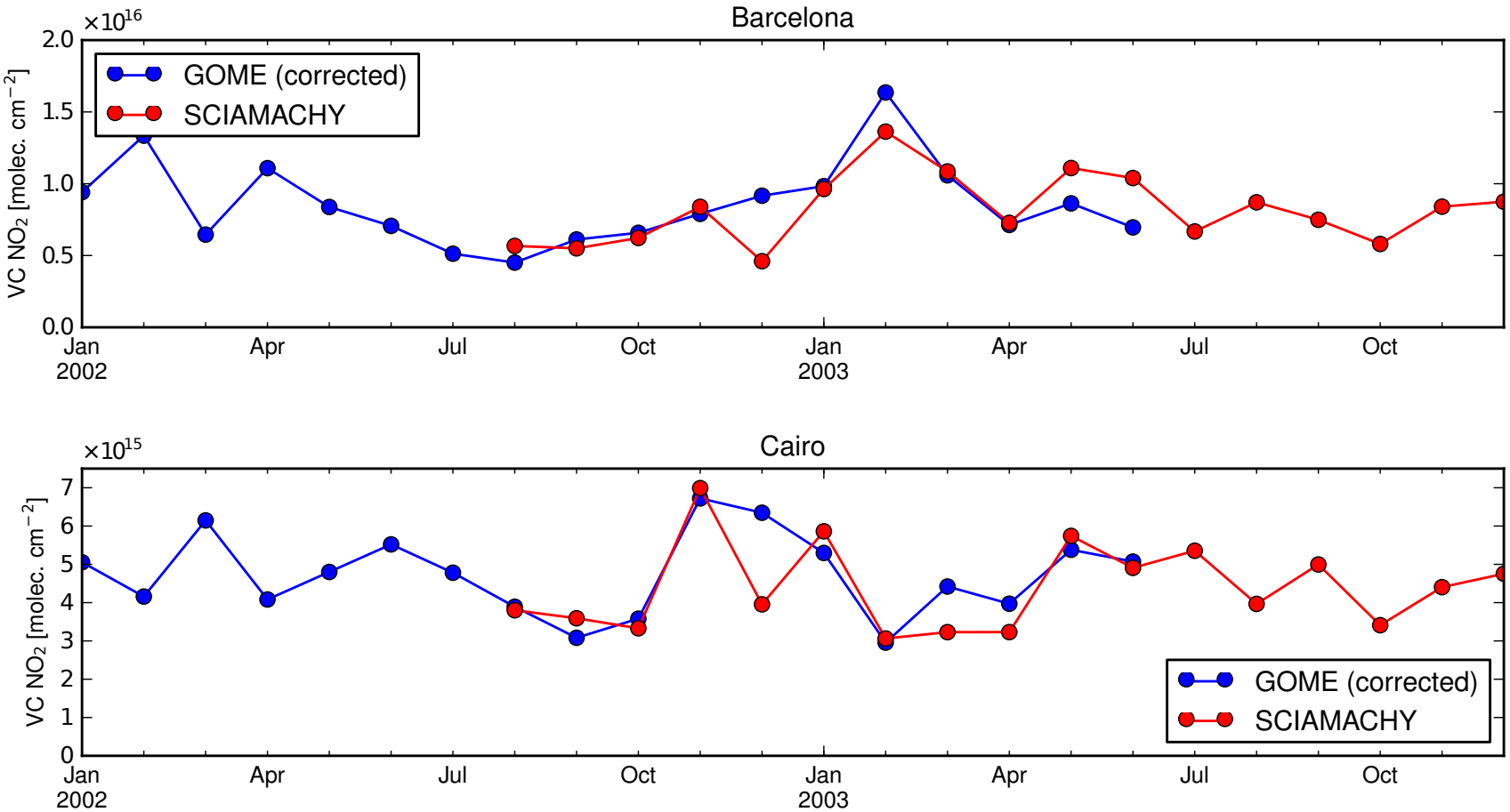
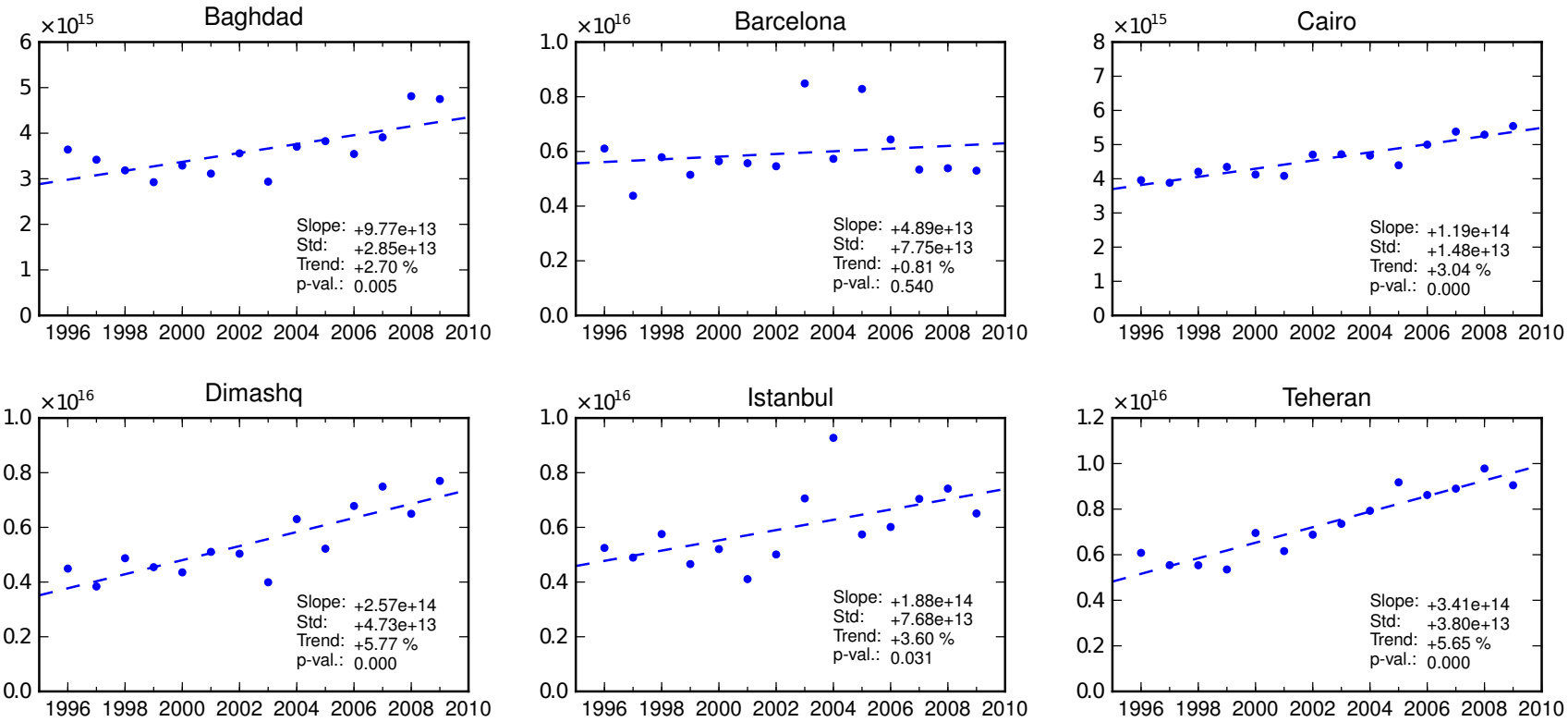


Linear trends over selected megacities

Annual summer mean values (Jun-Aug),
1996-2002 (GOME) & 2003-2009 (SCIAMACHY)



Summary

Observed trends for the MedME region, summer months 1996–2009

City	annual growth rate
Algiers	+ 3.9 ± 0.9%
Ankara	—
Athens	—
Baghdad	+ 2.7 ± 0.8%
Barcelona	—
Cairo	+ 3.0 ± 0.4%
Dimashq	+ 5.8 ± 1.1%
Istanbul	+ 3.6 ± 1.5%
Jeddah	+ 3.5 ± 0.7%
Madrid	—
Milan	—
Riyadh	+ 2.6 ± 0.5 %
Rome	—
Teheran	+ 5.7 ± 0.6%

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Summary

- Most investigated cities show upward tendencies
- Most cities show a considerable gap between GOME and SCIAMACHY timeseries
- Different pixel sizes pose big problems
- Here, we used the ratio of SCIAMACHY forward scan and back scan measurements to correct for the influence of pixel size
- Significant linear upward trends could be found for most eastern cities
- Western cities show no significant trend

Acknowledgements

- Björn-Martin Sinnhuber for providing B3dCTM data
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- TEMIS for providing FRESCO+ data
- CityZen for funding travel to EGU2010 (`http://cityzen-project.eu`)
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