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Results from one decade of measurements from GOME and SCIAMACHY

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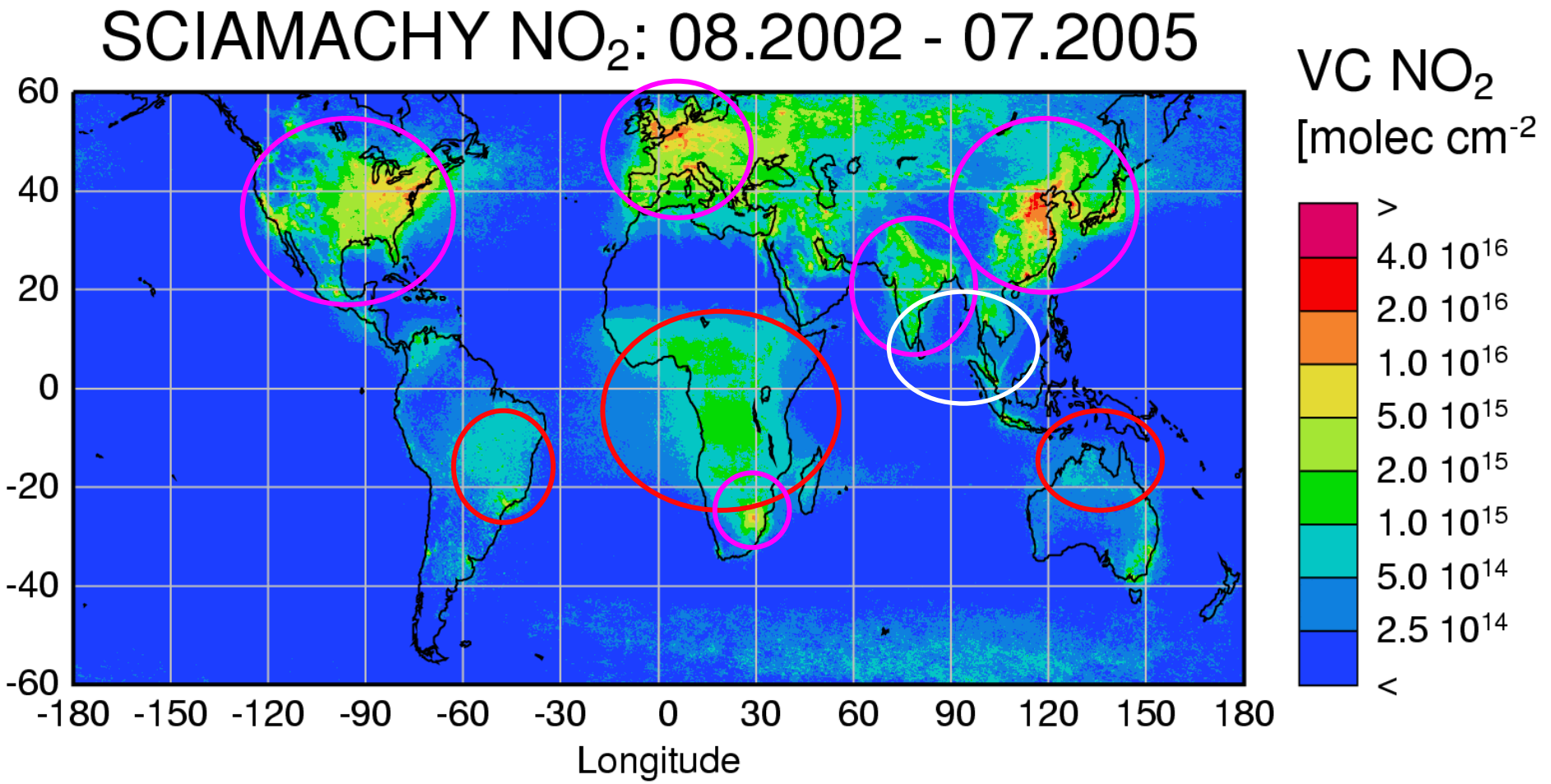
Overview

- **Introduction**
- **NO_2 :**
  - NO_x emissions from ships
  - emission changes
  - validation
- **BrO:**
  - polar BrO release
  - BrO from volcanoes
- **SO_2**
  - global distribution
  - comparison with aircraft measurements
- **OClO:**
  - Split Vortex event 2002
  - SCIAMACHY outlook

SCIAMACHY Tropospheric NO_2



pollution

biomass burning

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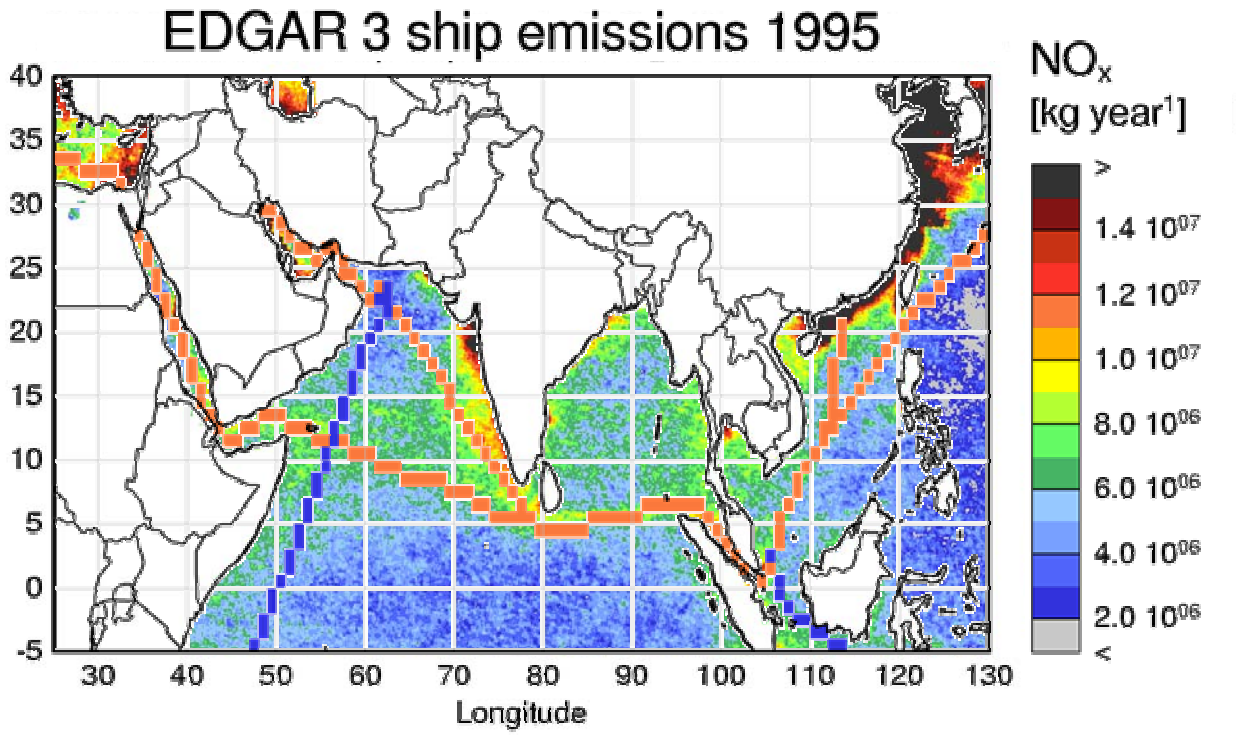
SCIAMACHY NO_2: Shipping Emissions



With estimate of NO_2 lifetime, NO_x emissions can be estimated => agreement within error bars.

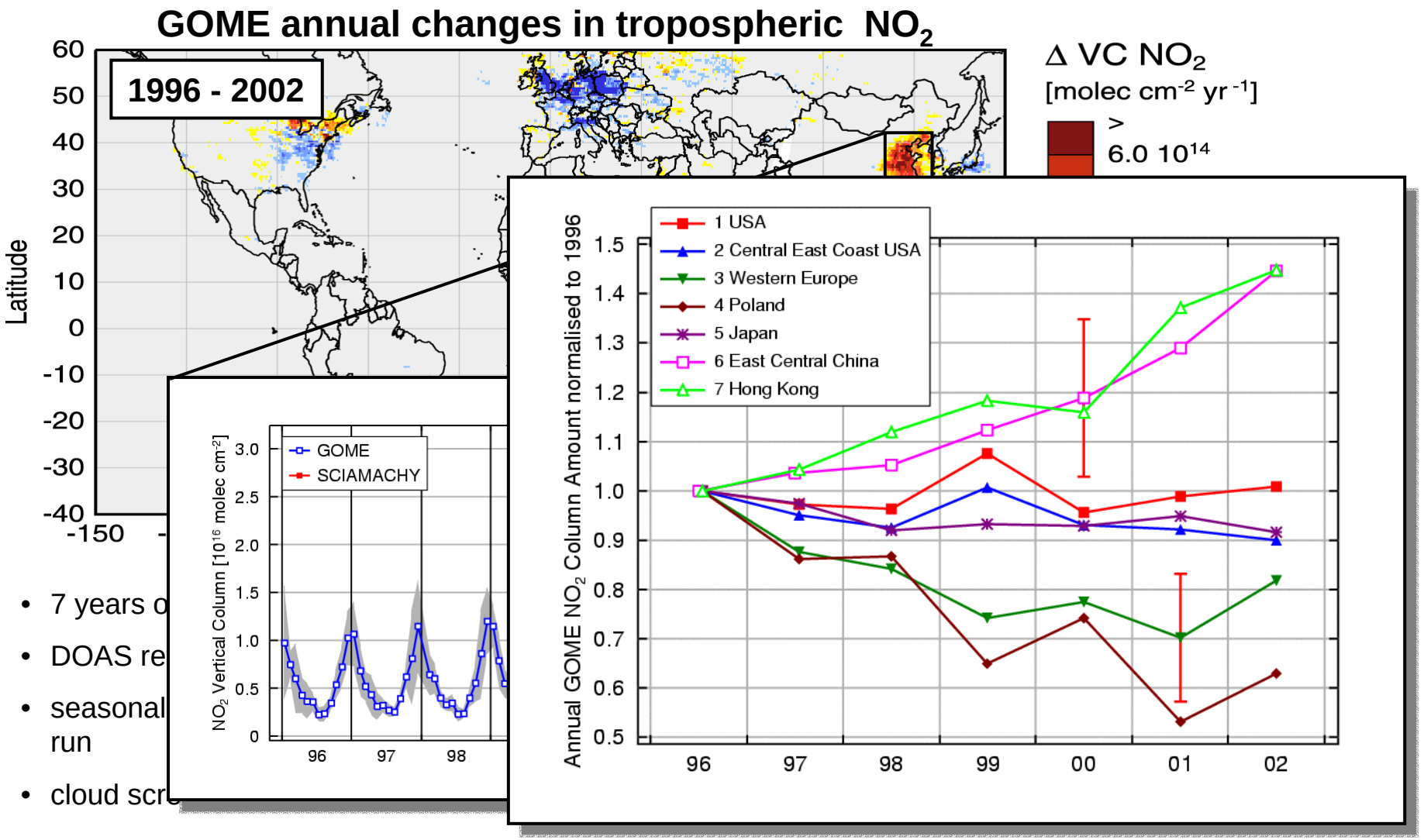
But: error bars still large (mainly from lifetime)

A. Richter et al., Satellite Measurements of NO2 from International Shipping Emissions, *Geophys. Res. Lett.*, **31**, L23110, doi:10.1029/2004GL020822, 2004

Ship emissions:

- large source of NO_x, SO_x and aerosols
- relevant input into marine boundary layer
- well defined NO_2-patterns in Red Sea and Indian Ocean in SCIAMACHY data
- consistent with pattern of shipping emissions

NO_2 trends from GOME



- 7 years o
- DOAS re
- seasonal run
- cloud scr

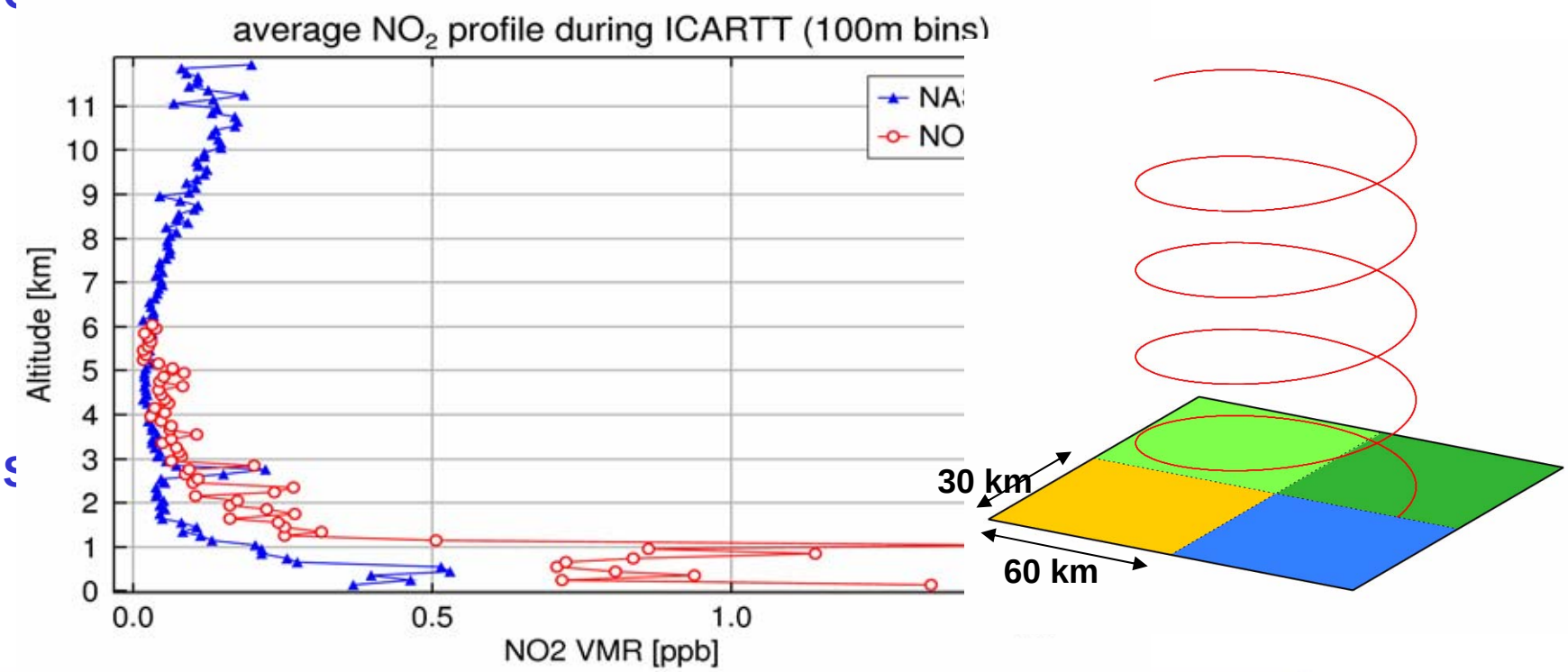
A. Richter et al., Increase in tropospheric nitrogen dioxide over China observed from space, *Nature*, **437** 2005

Validation of Tropospheric NO_2

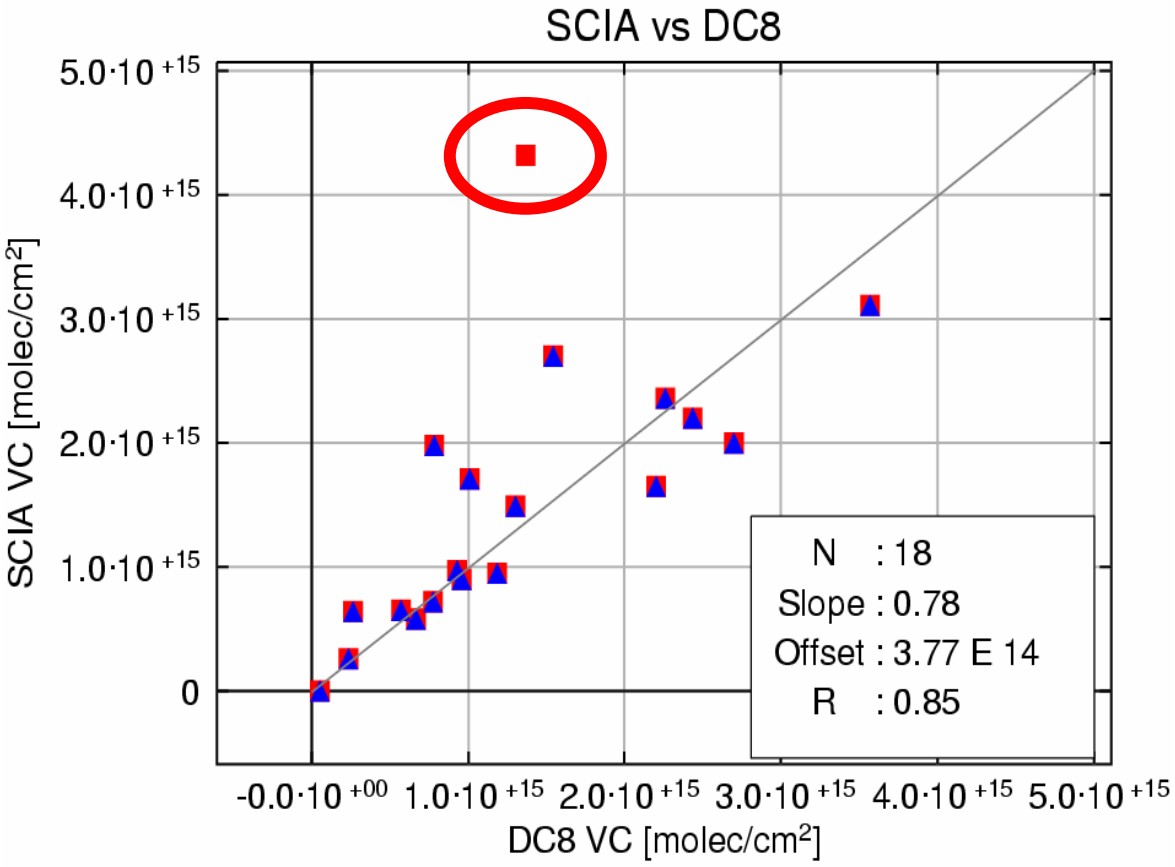
NO_2 distribution characteristic:

- Important sources are close to the ground
- Lowermost 1.5km make up to 50% of the tropospheric NO_2 column
- High spatial (horizontal AND vertical) variability

Characteristics of in-situ aircraft measurements



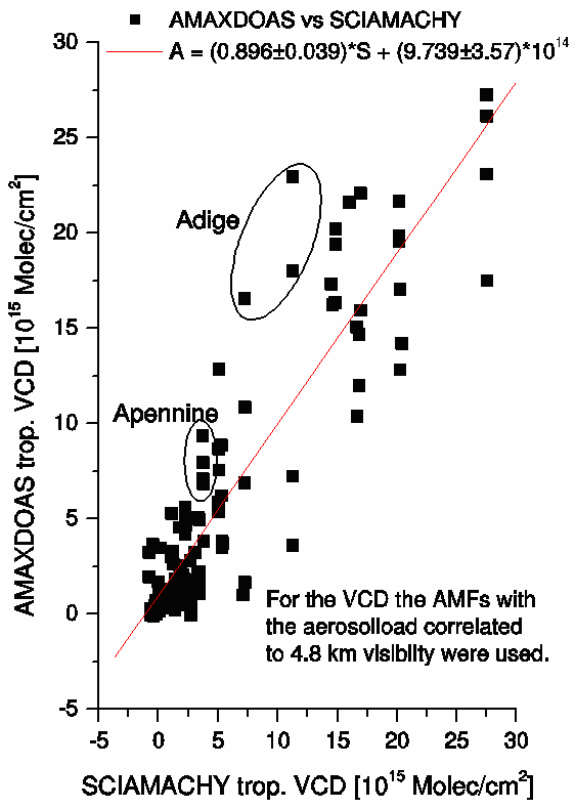
NO_2 validation using airborne in-situ measurements



- in-situ measurements on DC8 during ICARTT (data R. Cohen)
- SCIAMACHY limb-nadir tropospheric NO_2
- Difficult to find comparable measurements
- Strong dependence on the integration of the in-situ profiles
- spatial variability is a major problem

=> overall: good agreement

NO_2 validation using AMAXDOAS measurements

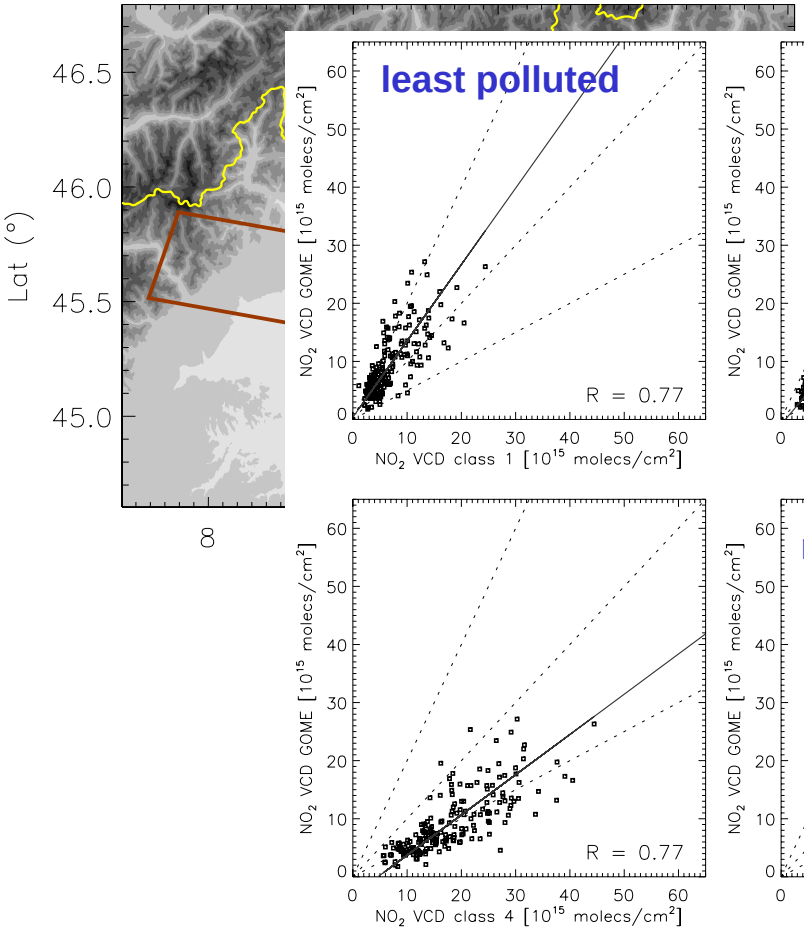


- Multi-Axis DOAS measurements on DLR-Falcon (SCIAVALUES campaign) over Alps & Po-valley
- direct comparison of tropospheric columns
- not completely independent (similar technique)
- smaller footprint of AMAXDOAS instrument

=> good agreement

Heue, K.-H., et al., Validation of SCIAMACHY tropospheric NO2-columns with AMAXDOAS measurements, *Atmos. Chem. Phys.*, **5, 1039-1051, 2005**

NO_2 validation using surface measurements



ORTHOGONAL REGRESSION (n=188)

stations 1:	slope = 1.32 ± 0.31	interc. = 0.38 ± 2.35
stations 2:	slope = 1.10 ± 0.25	interc. = −0.86 ± 2.59
stations 3:	slope = 0.86 ± 0.20	interc. = −2.36 ± 2.89
stations 4:	slope = 0.69 ± 0.16	interc. = −3.20 ± 3.11
stations 5:	slope = 0.53 ± 0.13	interc. = −2.66 ± 3.18

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Ordóñez C. et al., Comparison between 7 years of satellite-borne and ground-based tropospheric NO2 measurements around Milan, Italy, *submitted to J. Geophys Res.*, 2005

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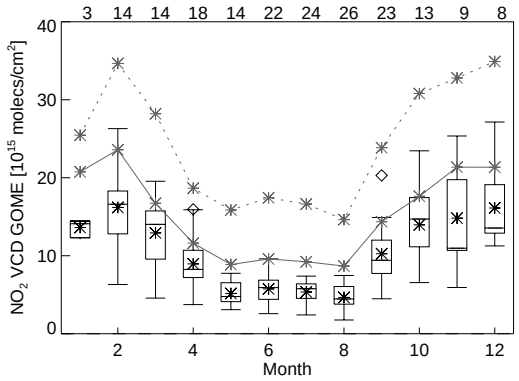
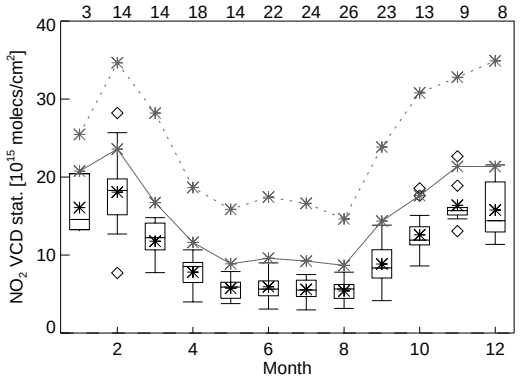
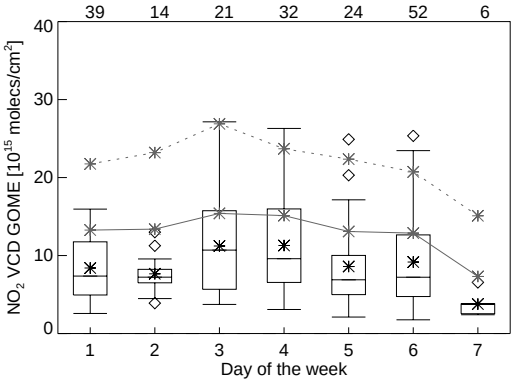
NO_2 validation using surface measurements

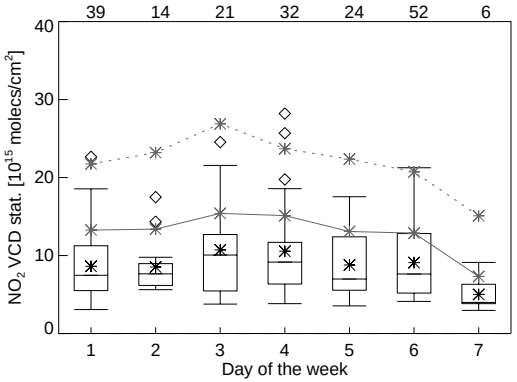
GOME **annual cycle** **in-situ**





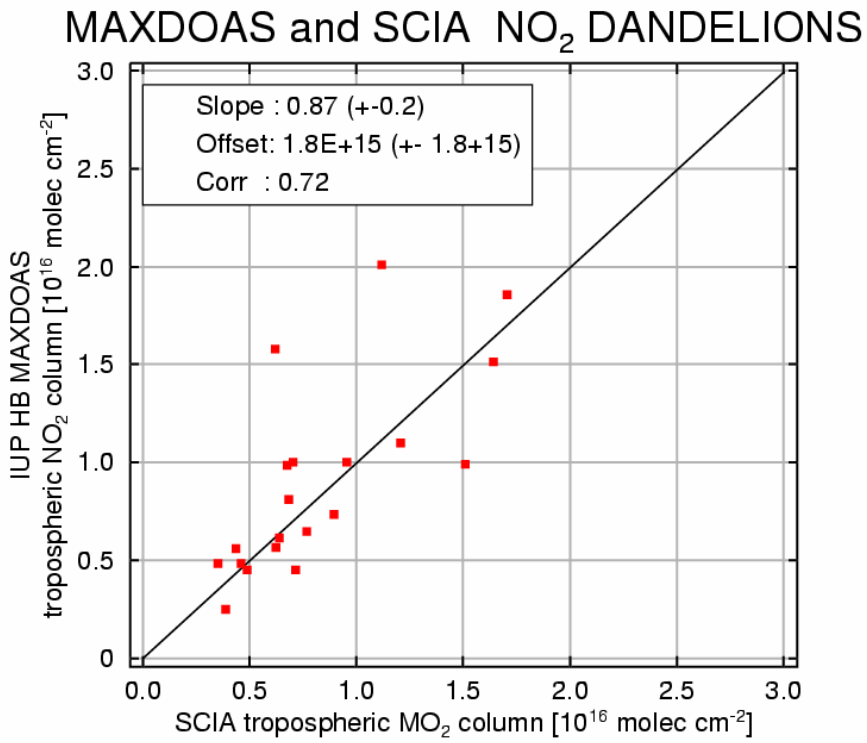
weekly cycle





=> good agreement in values, seasonality and weekly cycle, but large spatial variability

NO_2 validation using MAXDOAS measurements



⇒ **very nice agreement in spite of large uncertainties**

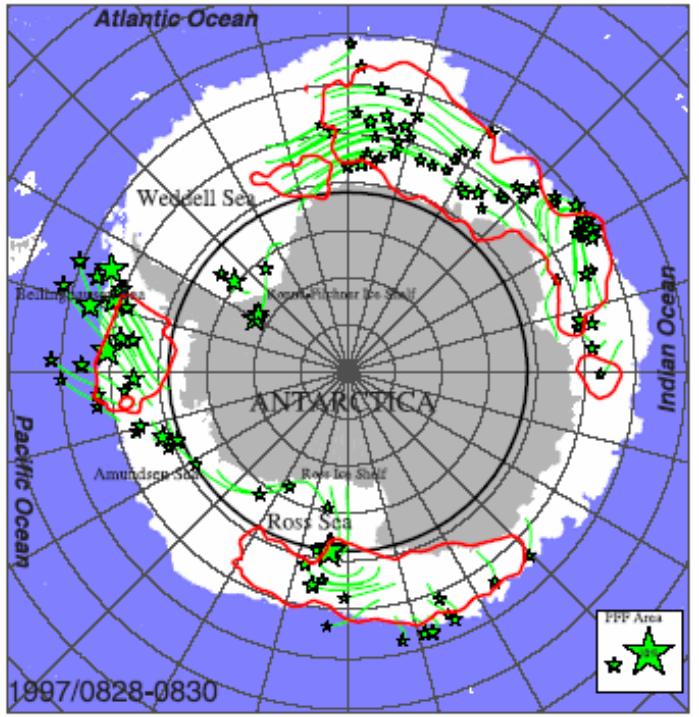
⇒ **good spatial matching crucial**

Analysis:

- MAXDOAS measurements in Cabauw during the DANDELIONS campaign
- May – July 2005
- tropospheric column determined from off-axis viewing directions
- Bremen SCIAMACHY tropospheric NO_2 product
- closest value within 50 km radius selected
- 20 overpasses with cloud fraction < 30%

Bromine Oxide (BrO) Release in Polar Spring

- Each year, large BrO columns are observed in polar spring over sea ice
- Bromine source is sea water, but release mechanism is not fully understood
- Correlation of GOME and SCIAMACHY BrO with areas with high probability for frost flower formation is indication for central role of frost flowers in bromine release



L. Kaleschke et al., Frost Flowers on Sea Ice as a Source of Sea Salt and their, Influence on Tropospheric Halogen Chemistry, GRL , 31, L16114, doi:10.1029/2004GL020655, 2004.

BrO Release from Volcanoes

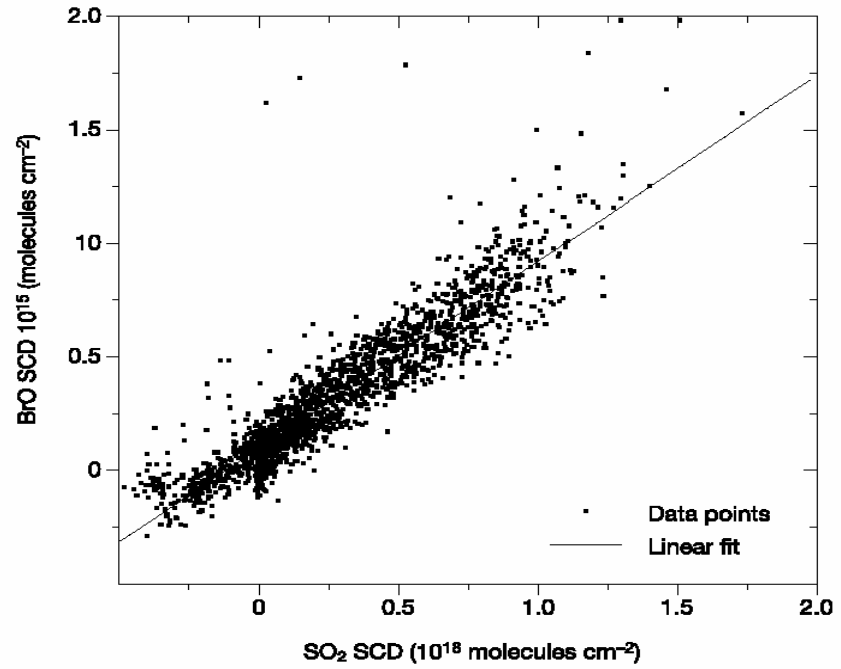


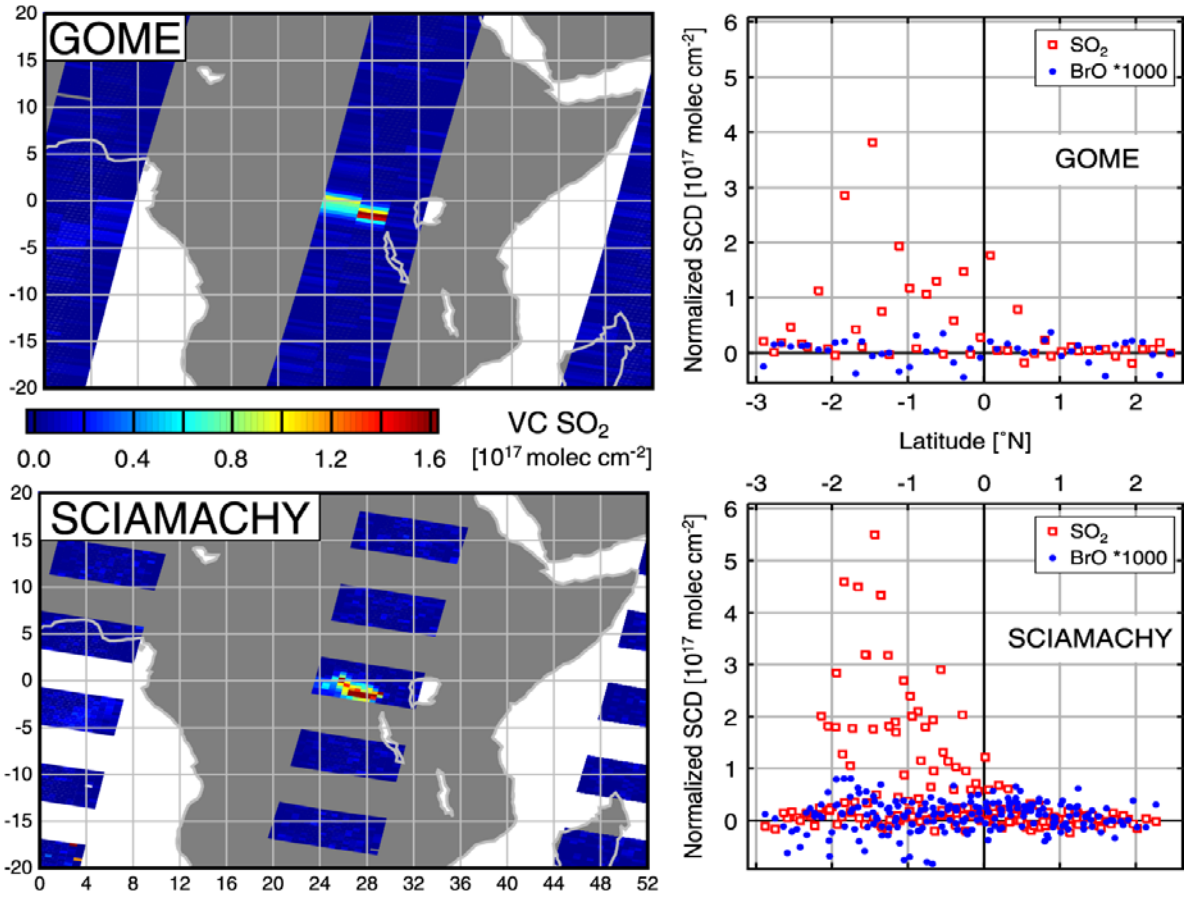
Figure 4 Plot of all data points, 23–31 May 2002. BrO is plotted as a function of SO_2; the equation of the linear fit is $BrO = 8.2 \times 10^{-4} SO_2 + 9.8 \times 10^{13}$; the species are well correlated with $R^2 = 0.81$. The molar ratio BrO/SO_2 is approximately 0.001.

- Ground-based MAXDOAS measurements at Soufriere Hills volcano (and others) show tight correlation between SO_2 and BrO emissions
- the ratio SO_2 / BrO was about 1000 at Soufriere Hills
- do satellite measurements show the same behaviour?
- satellites mainly detect large eruptions => search for large signals to get best SNR

Bobrowski, N. et al., (2003), Detection of bromine monoxide from a volcanic plume *Nature*, 423, 273-276.

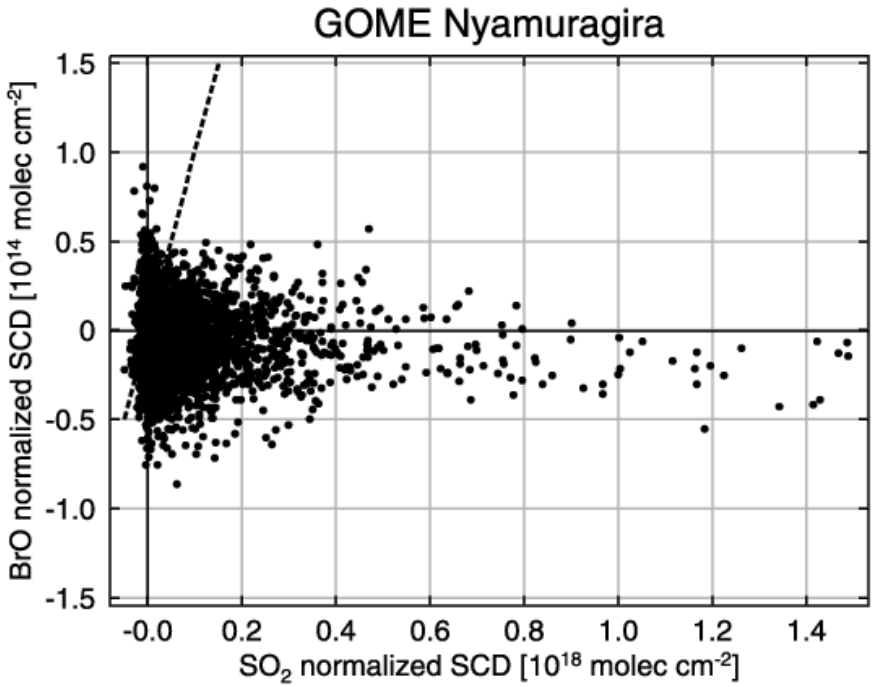
BrO Release from Volcanoes: GOME / SCIAMACHY

Nyamuragira: 1.41°S, 29.20°E
Summit elevation 3,058m

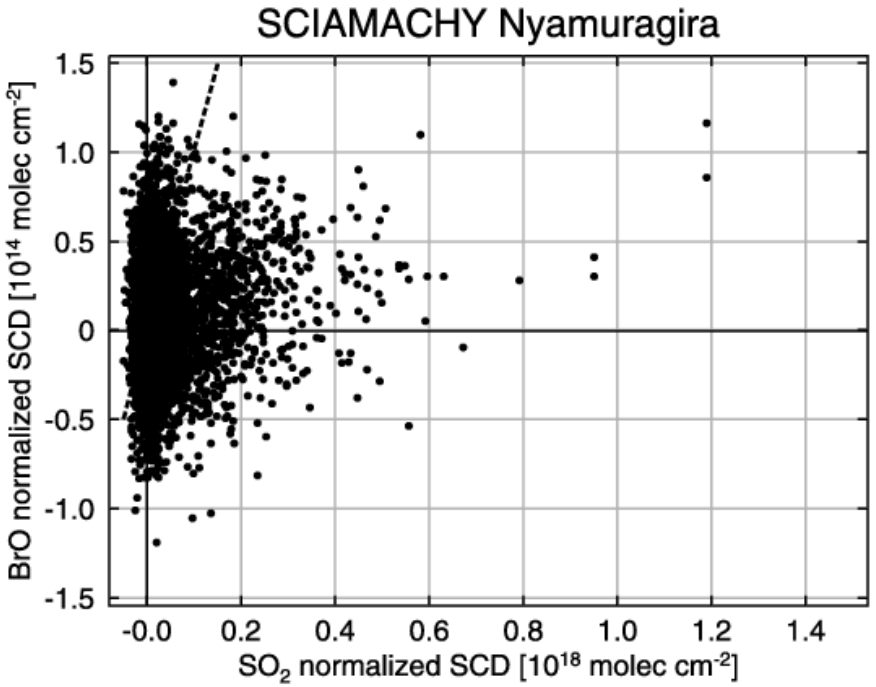


BrO Release from Volcanoes

GOME



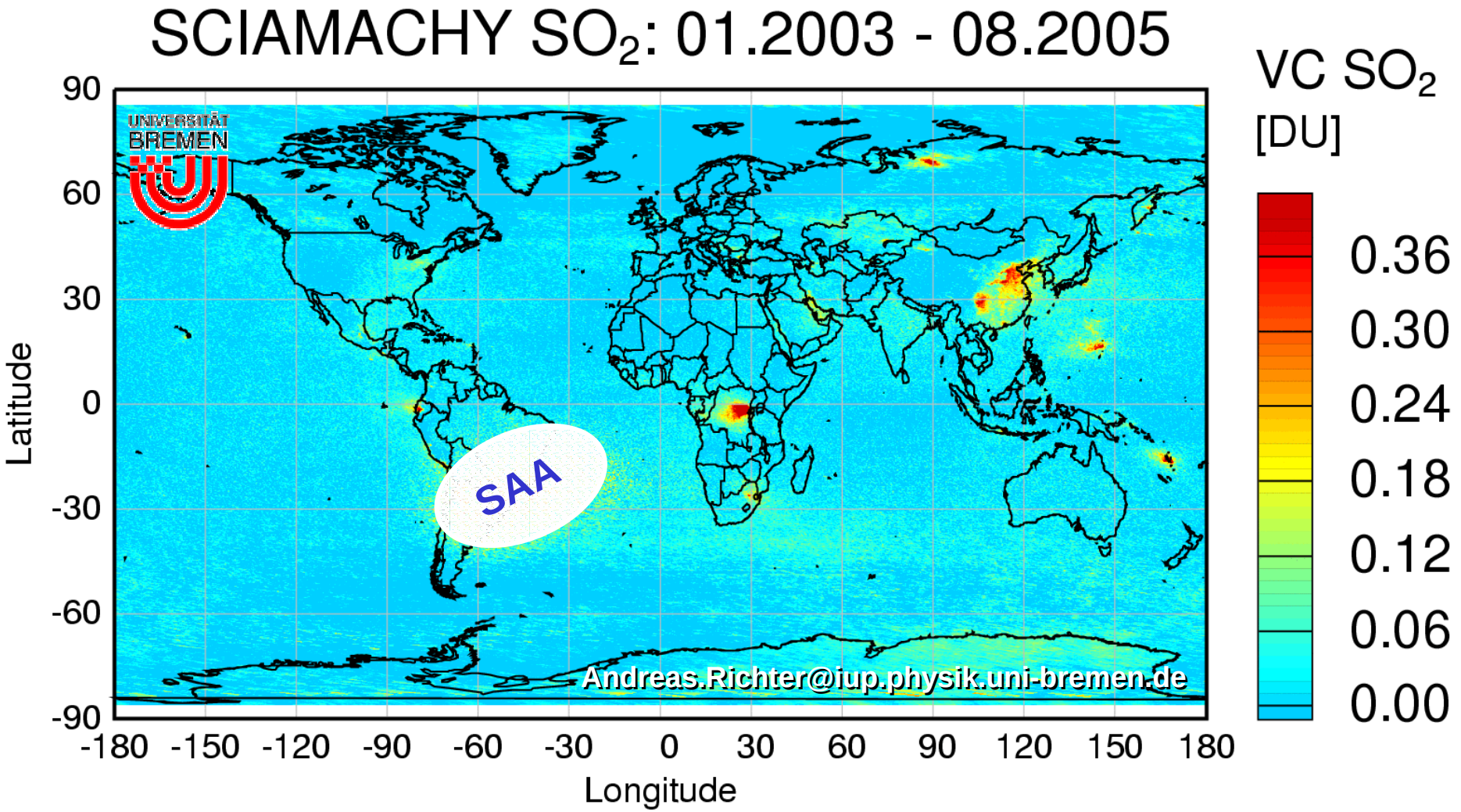
SCIAMACHY



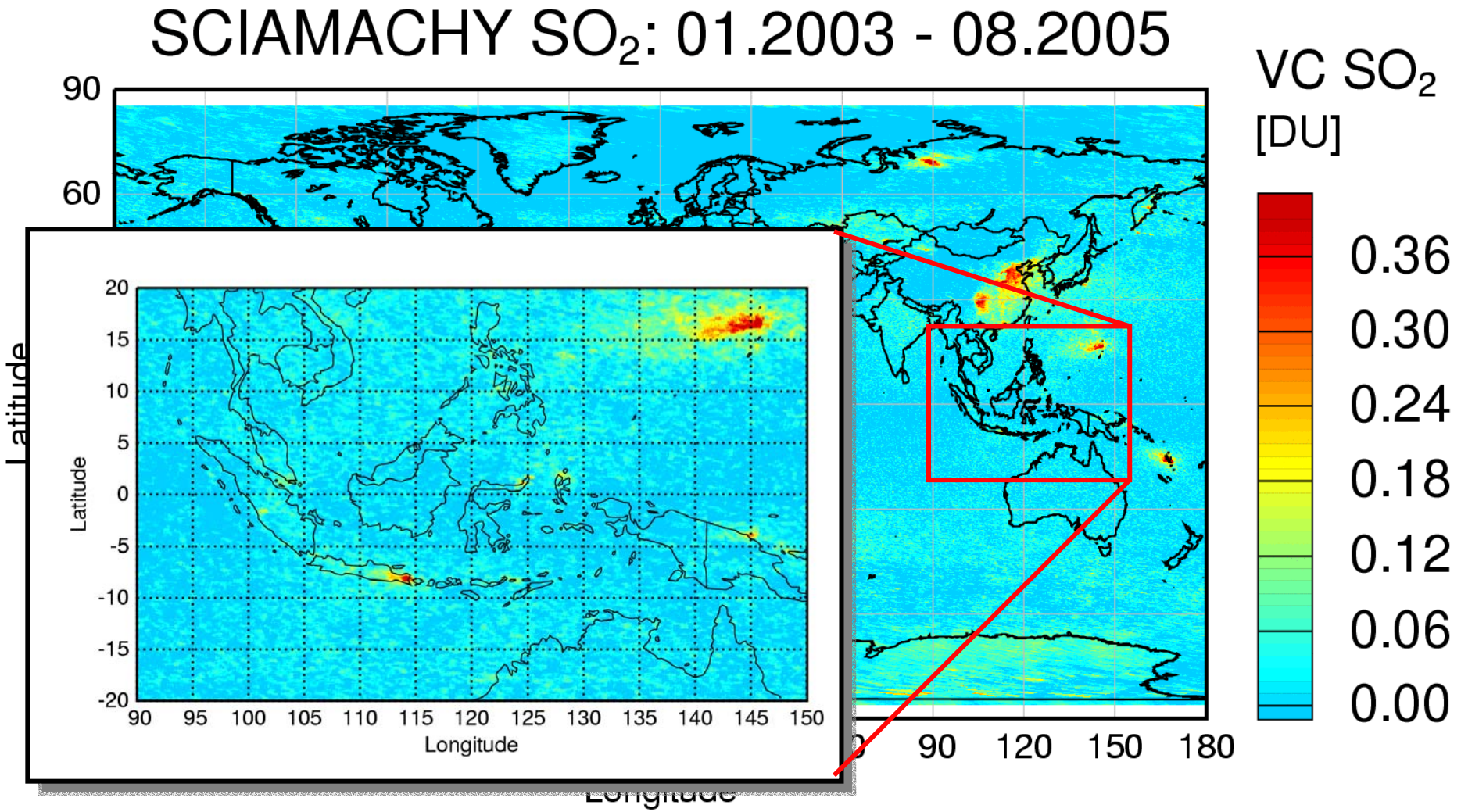
=> no indication for 1:1000 BrO / SO_2 emissions during large volcanic eruptions; difference to degassing?

Afe, O. T., et al., BrO Emission from Volcanoes - a Survey using GOME and SCIAMACHY Measurements, *Geophys. Res.Lett.*, **31, L24113, doi:10.1029/2004GL020994, 2004**

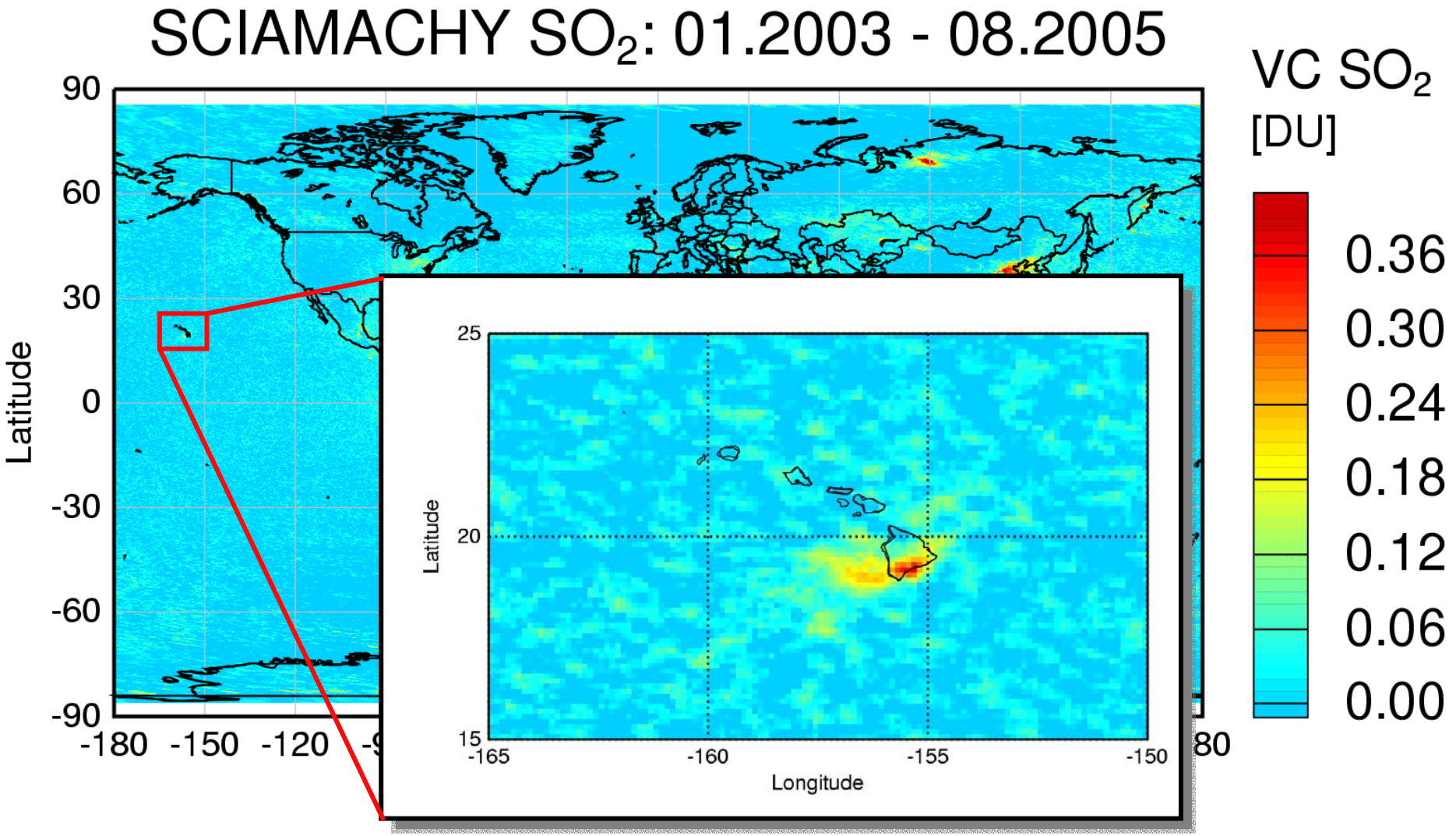
SCIAMACHY SO_2 measurements



SCIAMACHY SO_2: Volcanic Emissions



SCIAMACHY SO_2 : Volcanic Emissions



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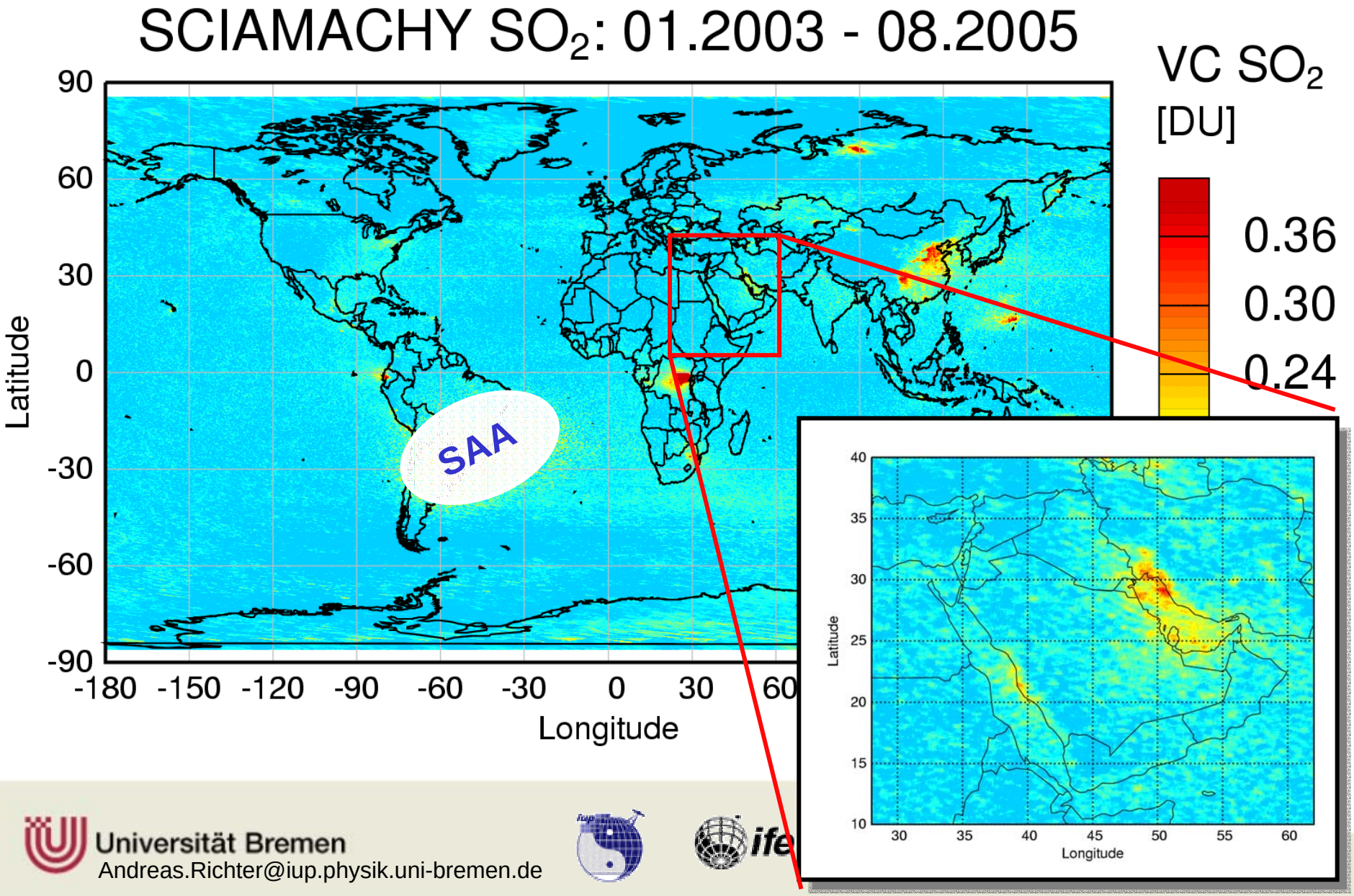
SCIAMACHY SO_2:Pollution



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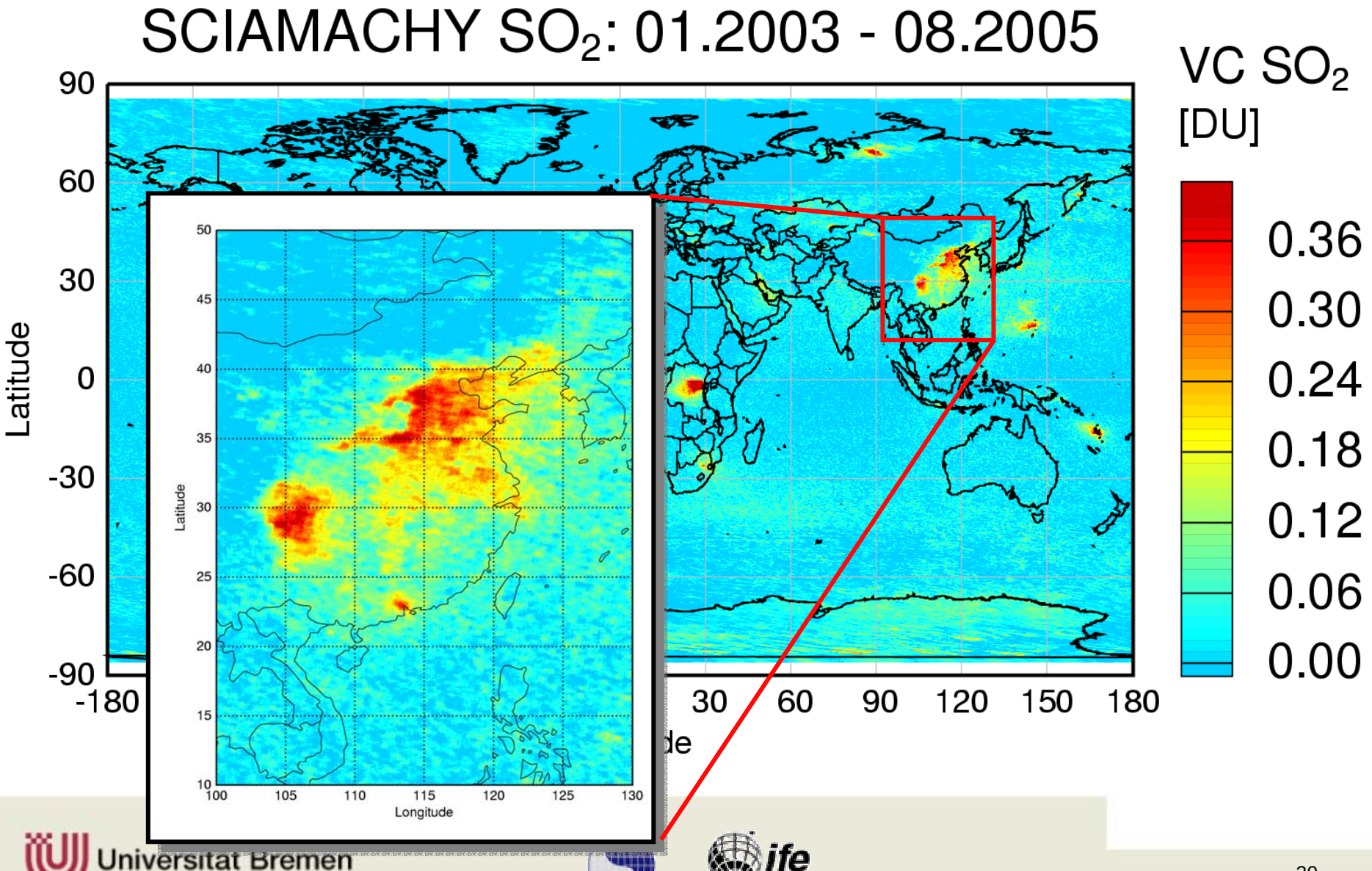
SCIAMACHY SO_2: Pollution



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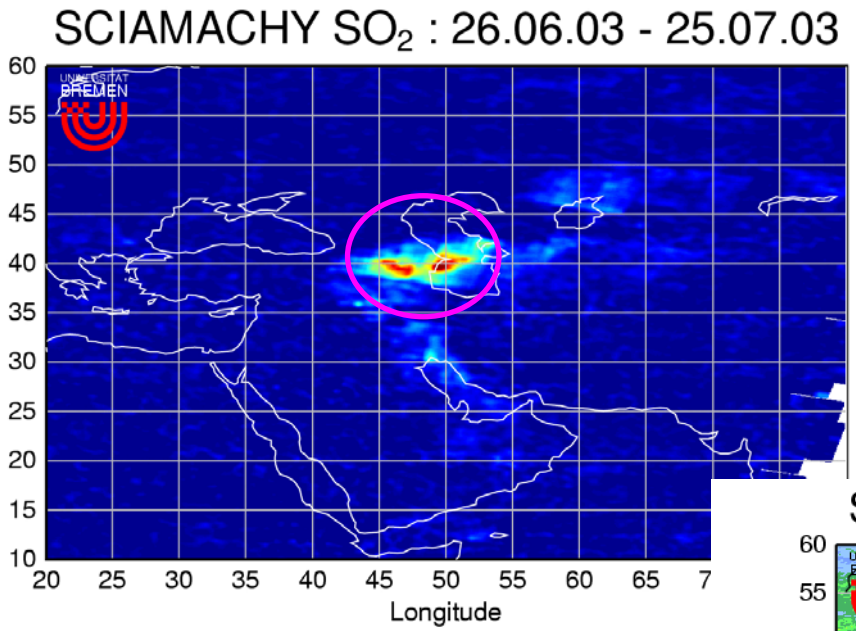
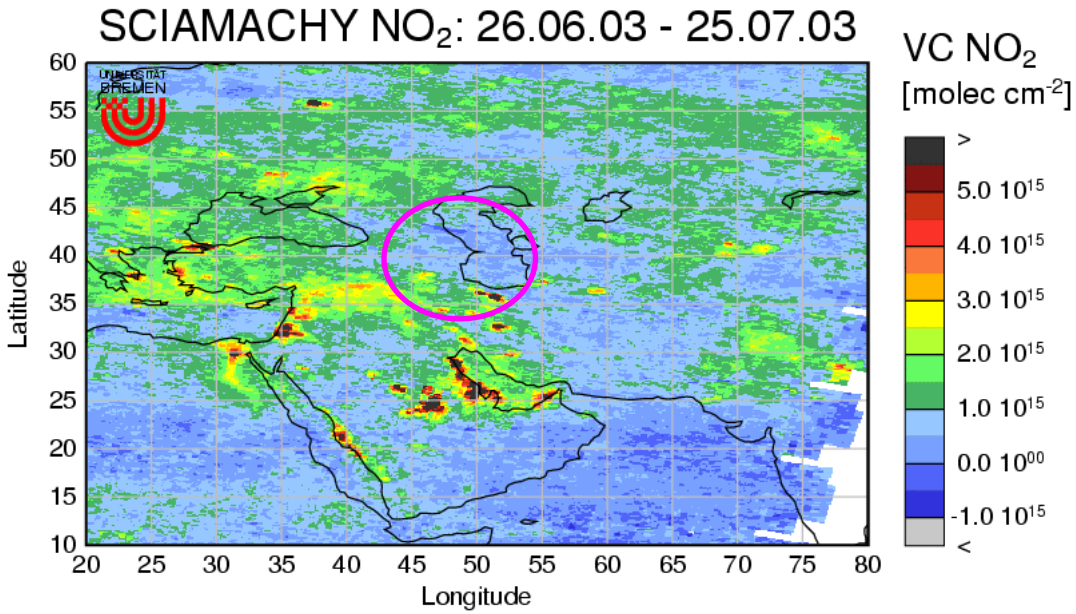
SCIAMACHY SO_2: Fire in Sulphur Plant



- **LARGE** SO_2 plume over Middle East in June / July 2003
- no matching NO_2 plume

- Fire in a sulphur plant in Qayyarah, Iraq



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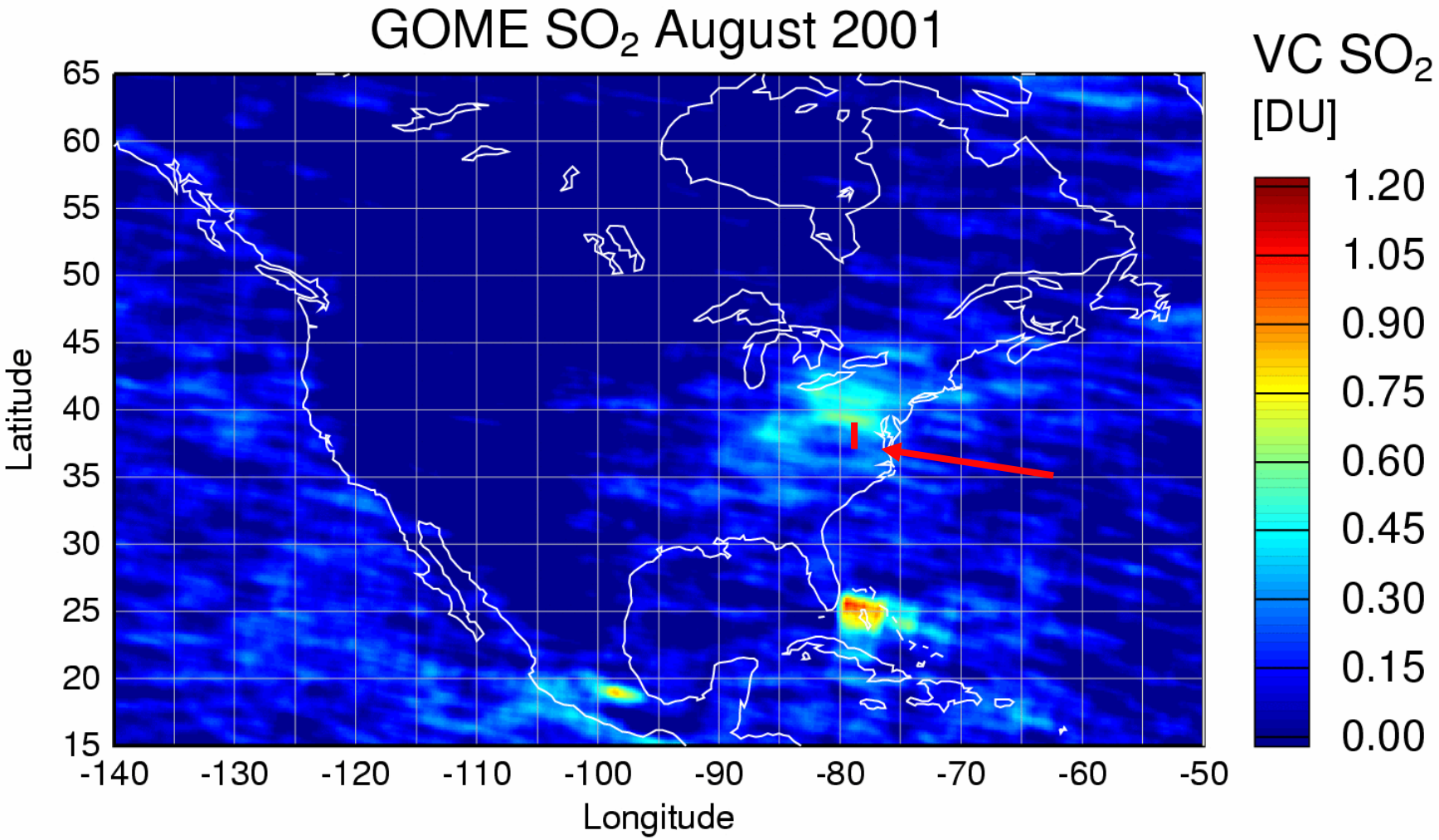
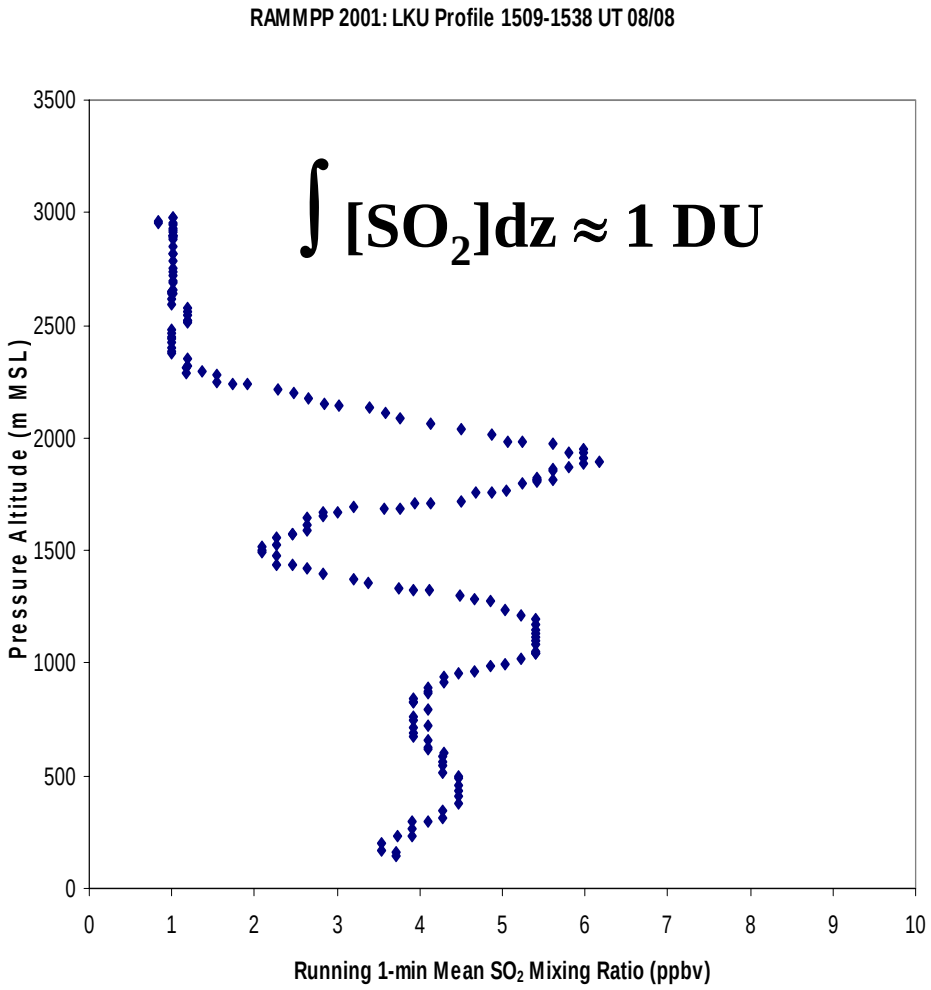
GOME SO_2 : Pollution in Eastern US

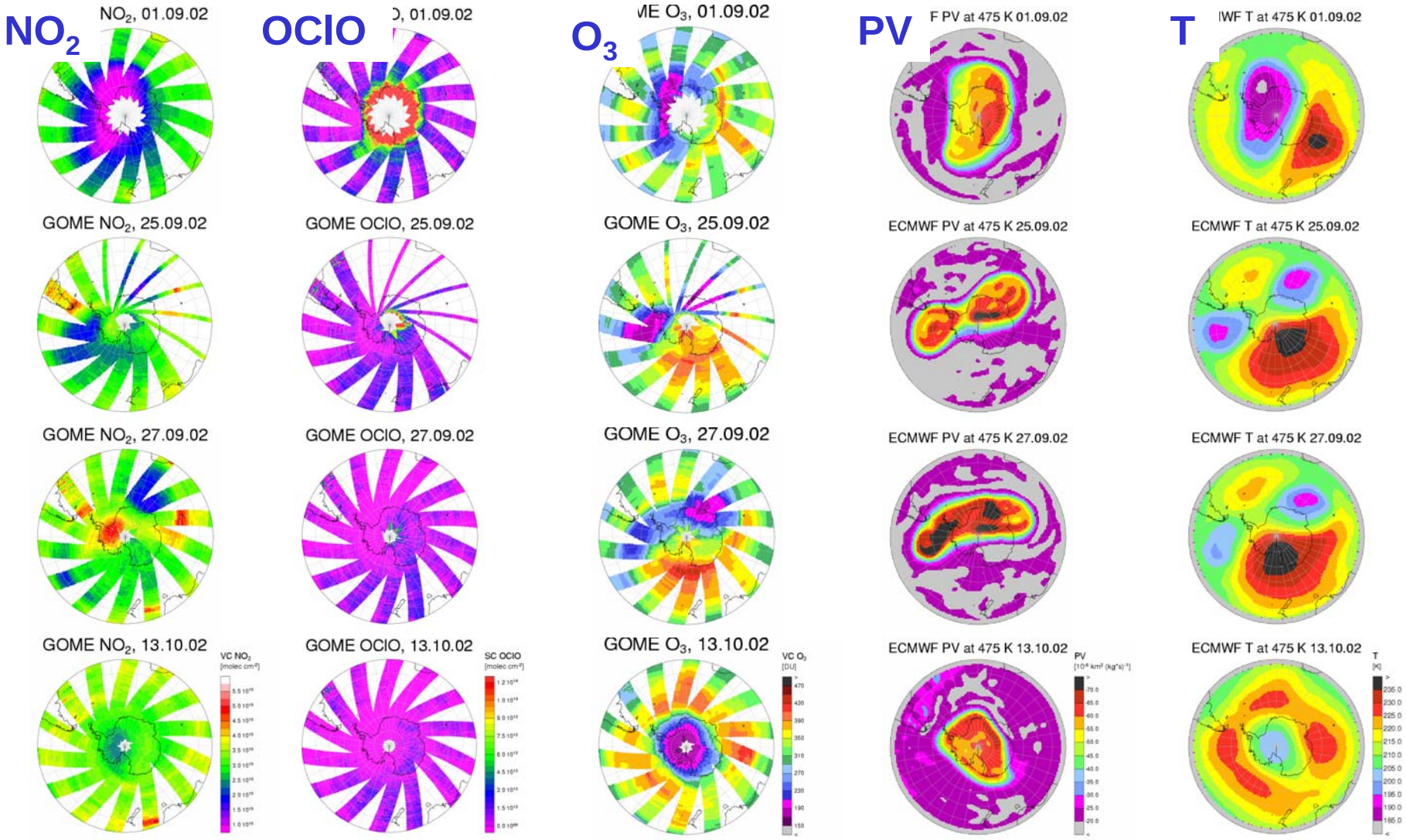


Comparison with RAMMP in-situ Measurements



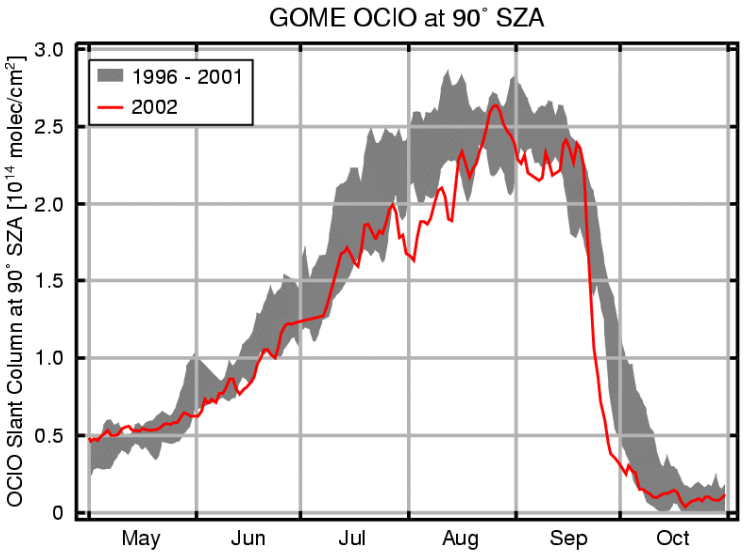
- air-borne in-situ measurements from Dickerson et al., University of Maryland
- flight from August 8, 2001
- vertical profile agrees well with assumptions in GOME analysis
- integrated column agrees well with GOME measurements
- more detailed comparisons are under way

GOME Observations of Split Vortex Event 2002



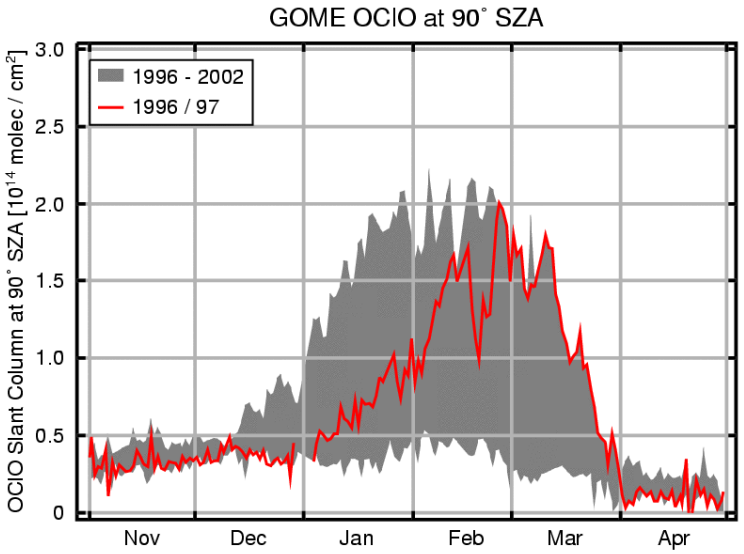
Chlorine Activation (OClO)

Southern Hemisphere



- small variability from year to year
- instability and early and rapid end of activation in 2002

Northern Hemisphere



- large variability from year to year
- lower activation even in coldest years

Richter, A., et al., GOME observations of stratospheric trace gas distributions during the splitting vortex event in the Antarctic winter 2002 Part I: Measurements, *J. Atmos. Sci.*, 62 (3), 778-785, 2005

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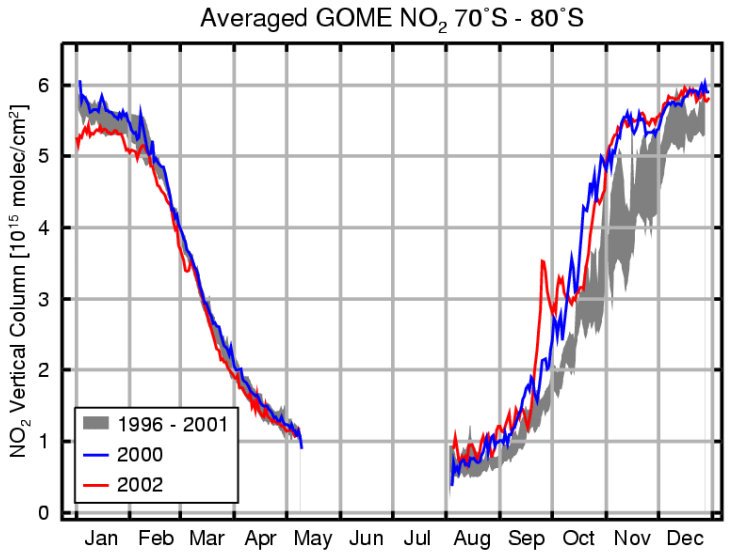
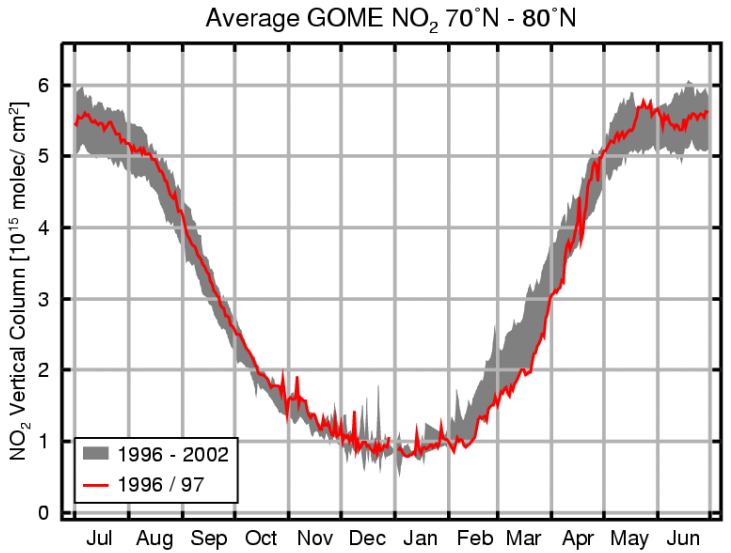
Denoxification / Denitrification (NO_2)

Southern Hemisphere



- small variability from year to year
- very large values in Sep / Oct 2002
- early recovery but not exceptional

Northern Hemisphere



- little variability from year to year
- no large excursions in spring
- recovery 1 month earlier than in SH

Richter, A., et al., GOME observations of stratospheric trace gas distributions during the splitting vortex event in the Antarctic winter 2002 Part I: Measurements, *J. Atmos. Sci.*, 62 (3), 778-785, 2005

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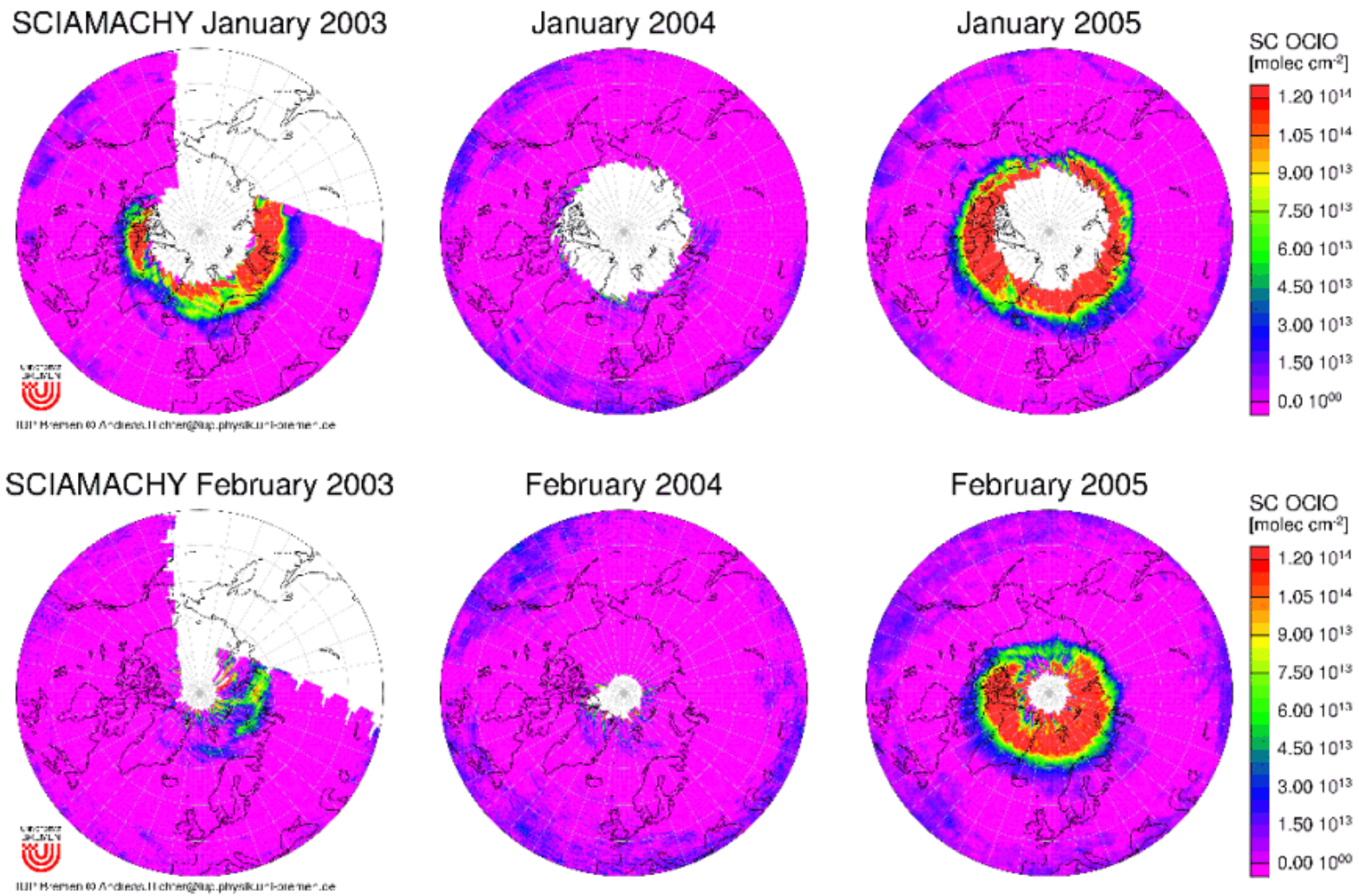
Stratospheric OClO SCIAMACHY



Summary

- GOME and SCIAMACHY provide a valuable long-term record of tropospheric and stratospheric measurements
- the long time series facilitates first “trend” studies
- long time series also improve sensitivity through averaging
- long time series are useful to detect rare events
- validation still is an issue, in particular for tropospheric products

OMI and GOME-2 will continue and improve the existing data sets