IMPACT OF CLOUDS ON TROPOSPHERIC TRACEGAS RETRIEVALS

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ABSTRACT

The sensitivity of nadir-viewing satellite observations for tropospheric columns is strongly affected by clouds: Clouds shield the column below, normally resulting in an underestimation of the actual total column. On the other hand, the high albedo of clouds, as well as multiple scattering within the cloud, increase the visibility of trace gases at and above the cloud top. The observed Tropospheric Slant Column Densities (TSCDs) are thus sensitive to the NO_2 profile.

Here we analyze the empirical dependency of tropospheric NO_2 slant column densities (TSCDs) on cloud fractions. The observed ratio of TSCDs for cloudfree versus clouded scenes shows strong regional variations; high values are observed over sources, where the NO_2 is close to the ground. Downwind from the sources, the ratio decreases, indicating a modification of the NO_2 profile.

1. INTRODUCTION

Spectroscopic measurements from nadir-viewing satellite platforms allow the retrieval of column densities of several atmospheric trace gases. The sensitivity for tropospheric columns is thereby strongly affected by clouds : Clouds shield the column below, normally resulting in an underestimation of the actual total column. On the other hand, the high albedo of clouds, as well as multiple scattering within the cloud, increase the visibility of trace gases at and above the cloud top.

Cloud parameters like cloud fraction, cloud top height or cloud heterogeneity can also be directly deduced from satellite measurements, using intensity measurements and spectral absorption features of O_2, O_4 or the so-called "Ring-effect".

Here we analyze the dependency of tropospheric NO_2 slant column densities (TSCDs) on cloud parameters. NO_2 TSCDs are retrieved from measurements of the SCanning Imaging Absorption SpectroMeter for Atmospheric CHartographY SCIAMACHY on ENVISAT for the years 2003-2006. Cloud information is taken from the Fast Retrieval Scheme for Cloud Observables (FRESCO , see www.temis.nl) and the Heidelberg Iterative Cloud Retrieval Utilities (HICRU , see http://satellite.iup.uni-heidelberg.de/). FRESCO derives cloud fraction and cloud top height from the oxygen A-band absorption. HICRU uses the intensity measurements of the Polarization Monitoring Devices (PMDs) with high spatial resolution and thus provides additional information on the cloud homogeneity.

To avoid misinterpretation of snow/ice as clouds, we only consider summer months . The study of cloud dependency of TSCD is done for polluted regions in the USA, Europe and Eastern Asia.

This empirical study is complemented by theoretical radiative transfer modelling studies using the 3D-Monte-Carlo Model TRACY-2 , that is in particular capable of modelling radiative transfer in clouds. With these investigations we check, and hope to improve, our understanding on the different cloud effects on radiative transfer (shielding, path-length enhancement and albedo increase). Improved knowledge on the impact of clouds on observed trace gas columns allows the interpretation of clouded pixels, that are currently discarded in most analyses.

In addition, temporal and spatial variations of the observed dependencies of NO_2 columns on cloud parameters hold information on the NO_2 profile.

In these proceedings, we concentrate on our empirical analysis of mean TSCD dependency on cloud fraction.

2. TSCD DEPENDENCY ON CLOUD FRACTION I: EXPECTATIONS

We assume that we can seperate a partly clouded scene in a clouded (f) and a cloud free (1-f) part. The observed SCD as function of cloud fraction S(f) would then be

$$S(f)= [(1-f)*I0*S0 + f*I1*S1] / [(1-f)*I0 + f*I1] \quad (1)$$

with S0/S1 being the SCD of the cloud free/clouded part and I0/I1 being the Intensity of the cloud free/clouded part respectively. I.e., S(f) is the sum of S0 and S1 weighted by cloud fraction and intensity. Fig. 1 illustrates the resulting dependecy of S on f.

In the following, we use eq. 1 to fit S0 and S1 from the observed dependency S(f), and define the „cloud shielding index" CSI as ratio of both:

$$CSI:=S1/S0 \quad (2)$$

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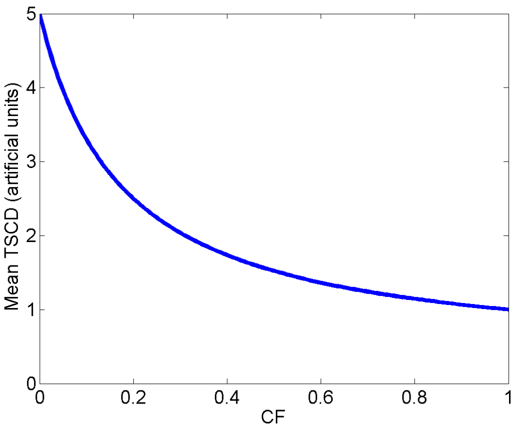

Fig. 1: Modelled dependency of TSCD on Cloud fraction according to eq. 1.

3. TSCD DEPENDENCY ON CLOUD FRACTION II: OBSERVATIONS

Fig. 2 and 3 displays the dependency of mean TSCDs on cloud fraction for polluted regions in the northern hemisphere. Fig. 4 shows maps of the mean TSCDs and the derived cloud shielding indices.

4. DISCUSSION

The cloud shielding index (CSI) shows strong regional differences (Figs. 2-4), holding information on differences in the NO_2 profile. The CSI is generally higher in East Asia. It depends on the absolute level of pollution (Fig. 2), though being a relative quantity. This indicates that the NO_2 is closer to the ground at the strong sources and more uplifted in the moderately polluted regions downwind. The CSI is higher for high clouds as expected (Fig. 3).

The regionally resolved maps show a lot of scatter due to the relatively poor statistics. Nevertheless, some features can clearly be seen: over most strong sources the CSI is high, while it decreases downwind. Highest values are found in the west of US, Europe and China, where the inflow is clean. So the NO_x ground sources in the western parts are the only signal in the SCD.

Further to the east, the CSI decreases since the pollution coming from the west and being uplifted is overlayn to the local emissions, leading to modified profiles.

5. CONCLUSION

Measurements of NO_2 TSCDs for partly cloudy scenes are sensitive to the NO_2 profile. By studying the dependency of TSCDs on cloud fraction, we deduce information on the „cloud shielding index“ that carries profile information.

Future improvements in cloud products and better statistics (including OMI and GOME-2 data) will be used to refine this study.

6. ACKNOWLEDGEMENTS

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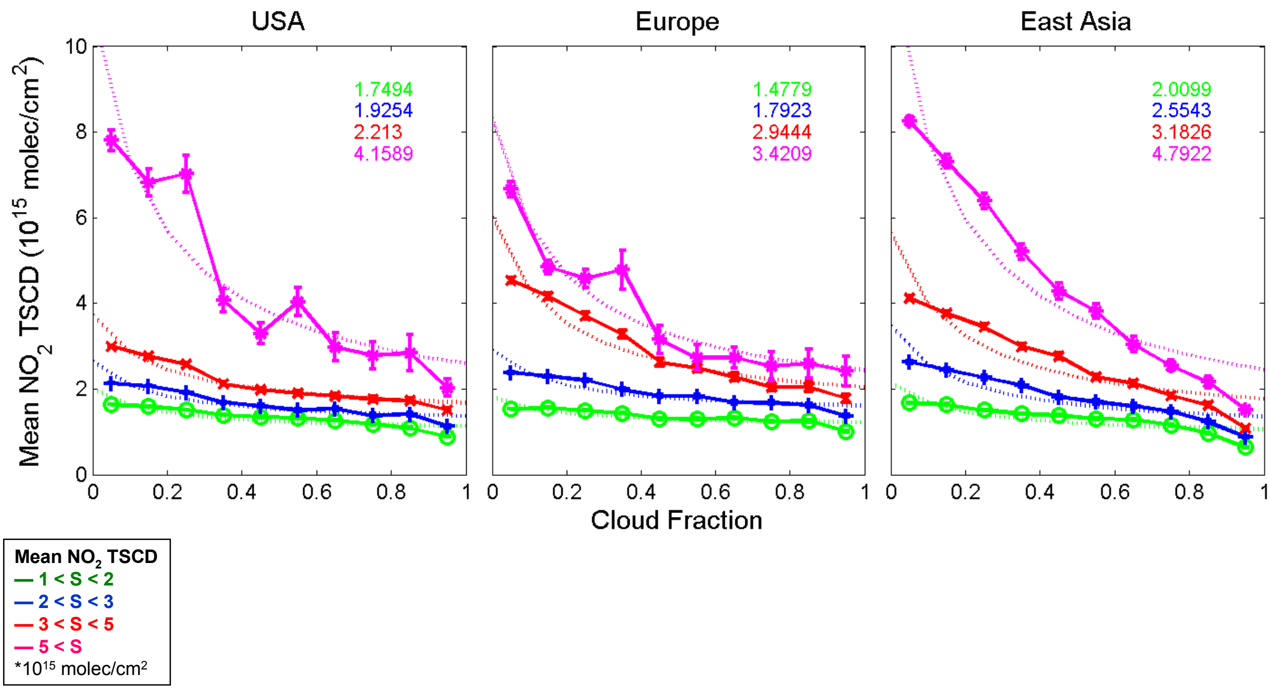

Fig. 2: Dependency of NO_2 TSCDs on cloud fraction for different regions of the world (left/middle/right) and for different pollution levels (colors). The dotted lines are fits according to eq. 1. The numbers give the respective cloud shielding indices.

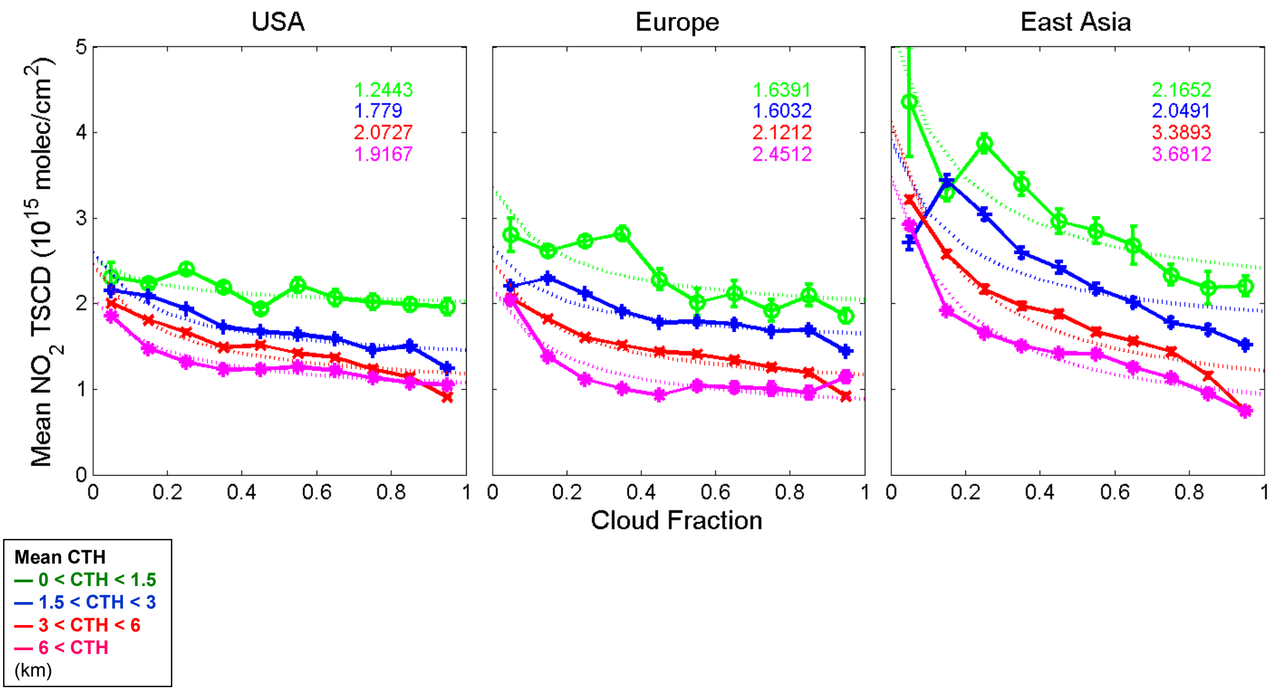

Fig. 3: Dependency of NO_2 TSCDs on cloud fraction for different regions of the world (left/middle/right) and for different cloud top heights (colors). The dotted lines are fits according to eq. 1. The numbers give the respective cloud shielding indices.

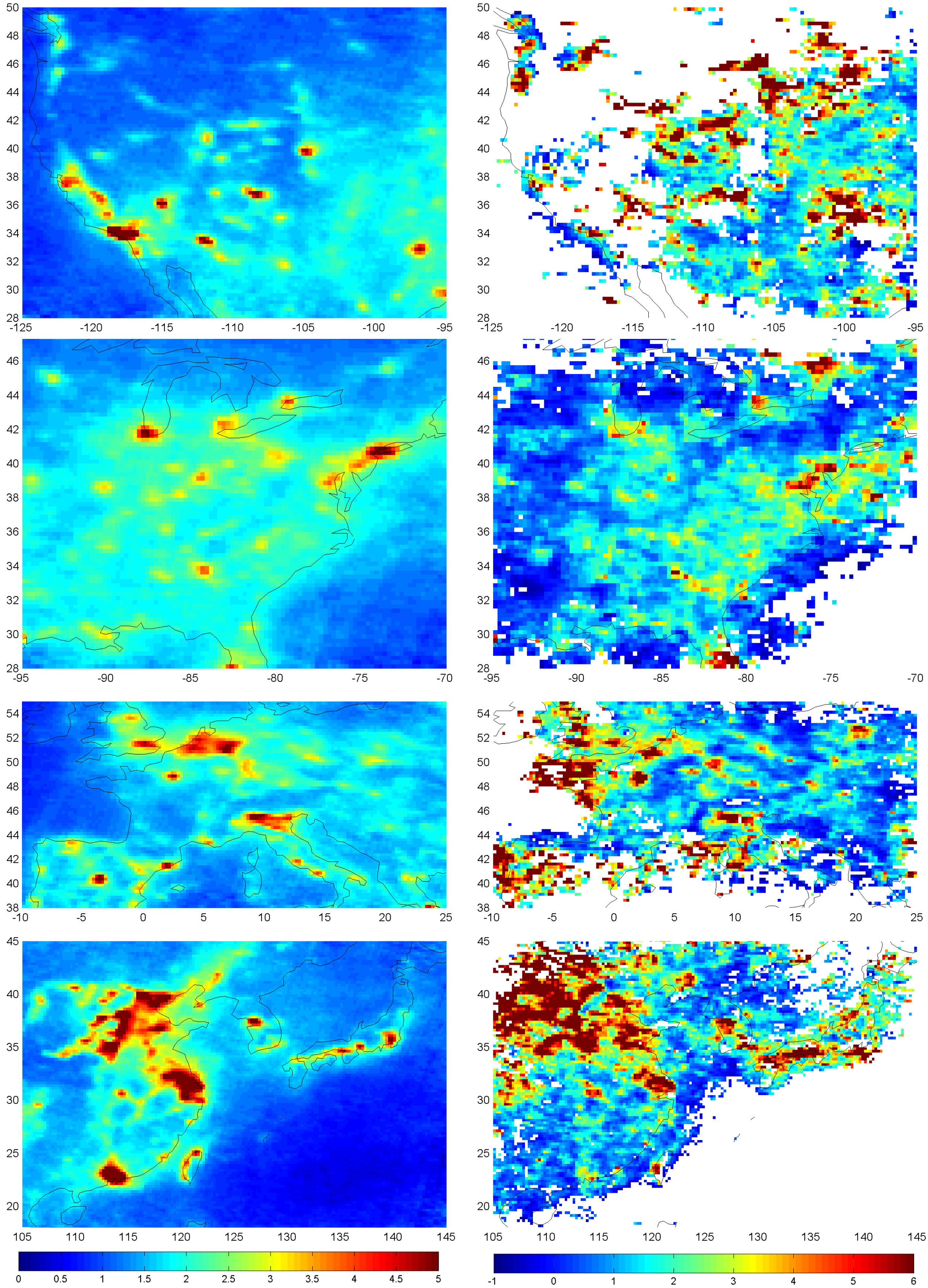

Fig. 4: Left: Maps of mean summer NO_2 TSCD (10^{15} molec/cm^2) for different regions of the world. Right: Maps of the cloud shielding index resulting from a fit according to eq. 1.