Cloud effects in satellite observed tropospheric NO_2

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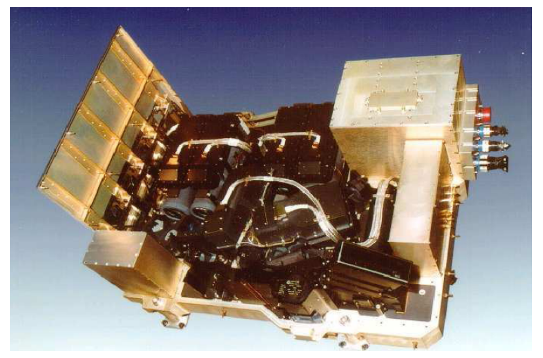
Introduction

- satellite observations of trace gases such as O_3, NO_2, or SO_2 provide important information on tropospheric composition
- clouds interfere with the retrievals and need to be taken into account
- study of variation in NO_2 signal for different cloud situations can give an idea on the uncertainties introduced and also on the vertical NO_2 distribution

Cloud Effects

- clouds **shield** the atmosphere below them from view
- clouds enhance visibility of trace gases above them (**albedo effect**)
- clouds enhance visibility of trace gases in their upper part (**multiple scattering**)
- the effect of clouds on the light path depends on cloud fraction, cloud height, NO_2 profile, surface reflectivity and aerosol loading
- the NO_2 vertical profile in the presence of clouds will differ from that under clear sky because of changes in photolysis, convection, uplifting in frontal systems
- the satellite observed signal is larger over clouds
- the interference from surface effects is smaller in cloudy scenes
- clouds can potentially also interfere with the spectral retrieval of NO_2

Instrument and Retrieval



GOME-2 Instrument:

- launched on MetOp-A in October 2006
- data since January 2007
- 4 channel nadir viewing UV/visible spectrometer
- first in a series of three identical instruments
- 80 x 40 km^2 pixel size
- global coverage in 1.5 days
- 09:30 LT equator crossing

DOAS Analysis:

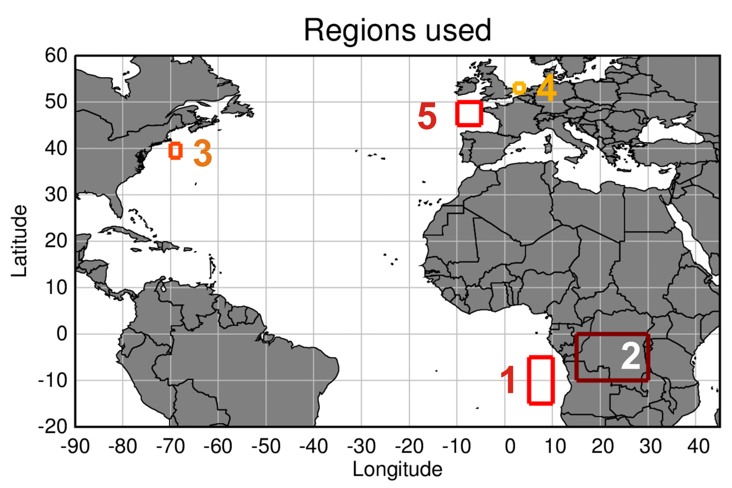
- 425 - 497 nm fitting window
- spectral spike correction
- liquid water cross-section to remove interference from water absorption

Stratospheric Correction:

- reference sector over the Pacific (180° - 220° E), no cloud screening

Airmass Factors:

- no airmass factor was applied



Acknowledgements

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- FRESCO data provided by EUMETSAT and KNMI
- GOME-2 lv1 data provided by EUMETSAT

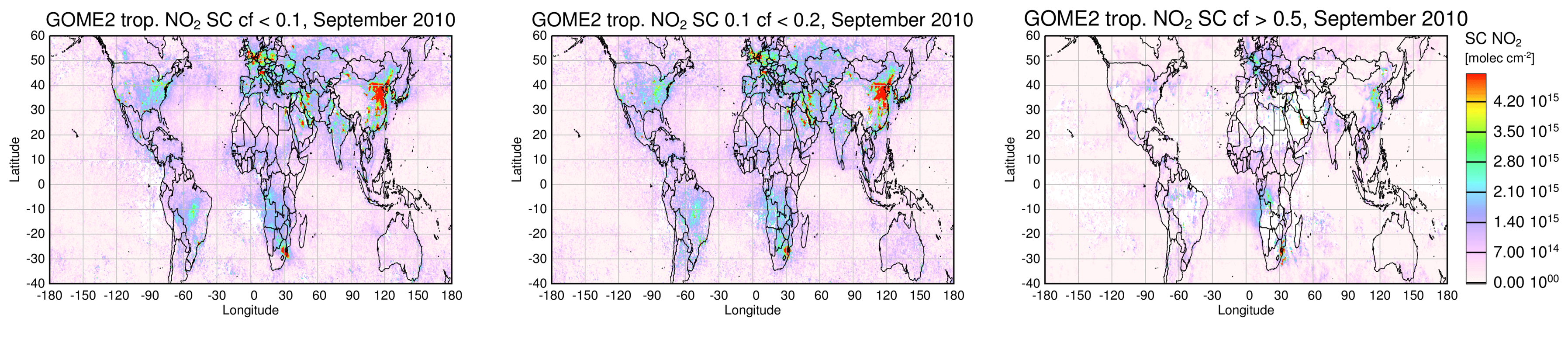
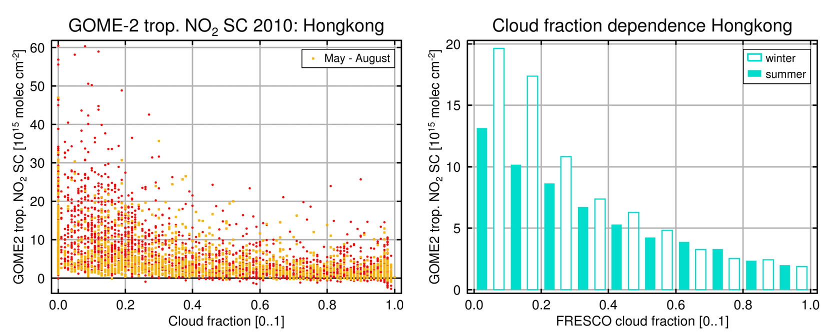


Figure top: Comparison of GOME-2 NO_2 slant columns for September 2010 using different cloud selection criteria of 0..0.1 (left), 0.1..0.2 (middle) and 0.5..1.0 (right). As can be seen, there are only moderate differences between the first two, but much reduced tropospheric signals for the last case. Note the occurence of sporadic hotspots over the oceans in cloudy measurements (transport and lightning). A reduction of values is observed for large cloud fractions also in unpolluted regions from shielding of the tropospheric background.

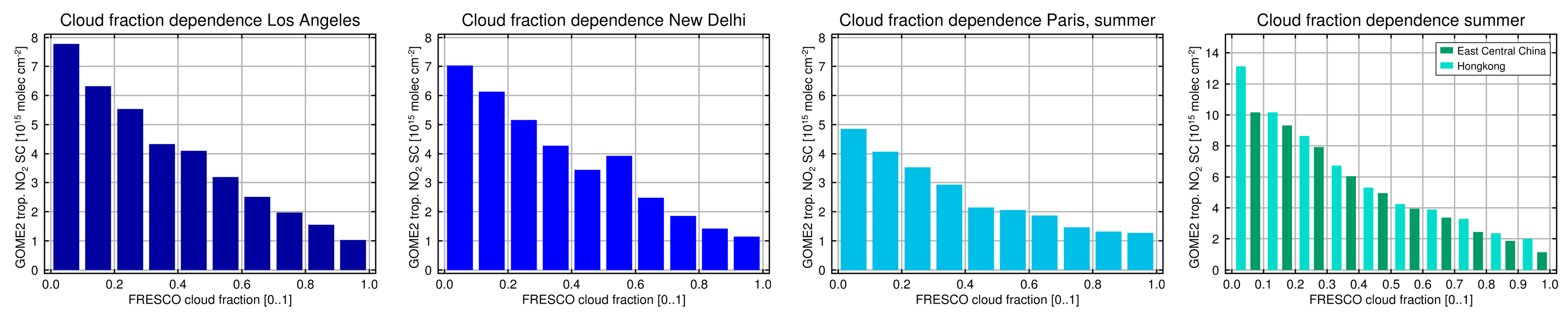
NO_2 dependence on cloud fraction

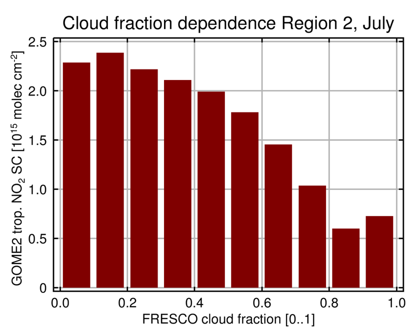
Approach:



- All data over an area was collected for 2009 and 2010 (unless noted otherwise) and grouped into cloud fraction bins
- very large scatter is observed even strongly polluted regions under clear conditions => atmospheric variability
- seasonal differences are observed over cities => less vertical mixing in winter leads to more shielding

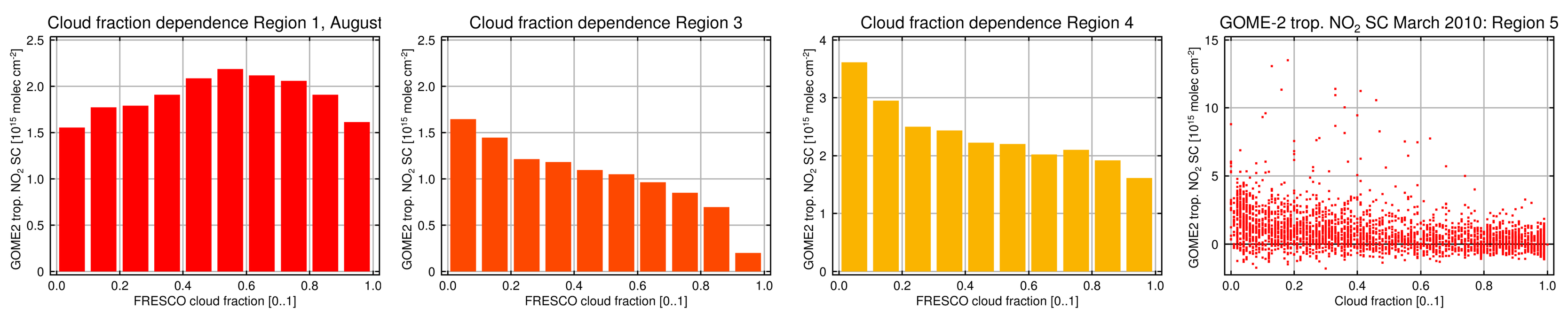
Pollution hotspots:





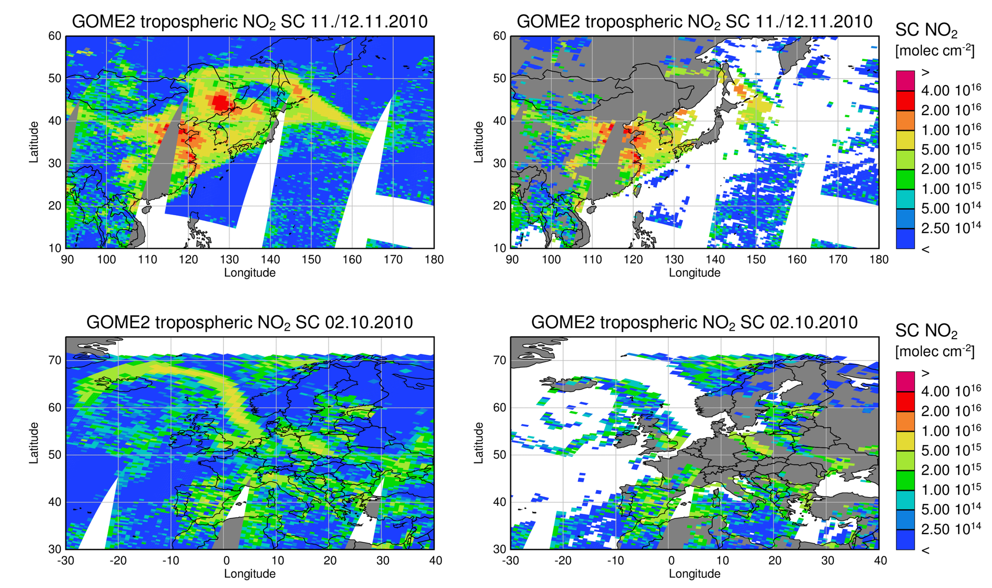
- rapid increase of tropospheric NO_2 slant columns for lower cloud fraction => most NO_2 close to the surface
- effect is most pronounced over hotspots, less over large polluted areas (e.g. Hongkong vs. East Central China)
- over biomass burning regions, smaller dependence on cloud fraction => elevated NO_2

Outflow regions:



- reduced cloud fraction dependence of NO_2 in outflow regions => mixture of transport above and below clouds
- inverted behaviour over outflow region west of Africa => NO_2 above low clouds
- as shown for region 5, individual events of very large NO_2 are found at all cloud fractions

Clouds and transport events



- many export events are associated to clouds
- NO_2 must be above clouds or within their top part to be visible from space
- cloudy and clear observations sometimes represent very different situations

Effect of simple cloud screening

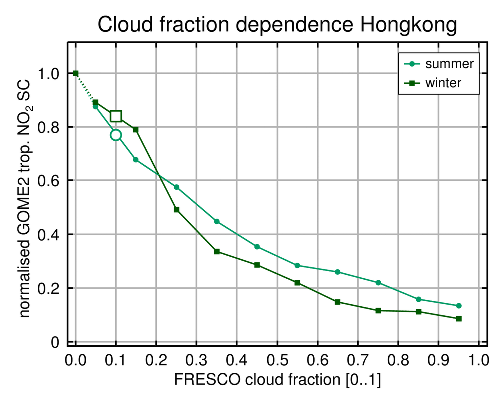


Figure: Normalised cloud fraction dependence. Dashed line is extrapolation by eye to 0 cloud fraction, large open symbol is value for cloud screening with cf < 0.2

- the current IUP NO_2 product applies only cloud screening (cf < 20% FRESCO), no additional cloud correction
- from extrapolation of cloud fraction dependence, this leads to underestimations of 23% in summer and 16% in winter over an intense hotspot such as Hongkong
- errors will be smaller in most other regions
- for individual measurements, errors can be much larger
- uncertainties in cloud fraction also affect these estimates

Conclusions

- clouds have large impact on tropospheric NO_2 columns over polluted regions
- retrieved slant columns are much larger for cloud free situations
- effect is largest over hotspots and in winter
- over export regions, results vary depending on altitude of clouds and NO_2 layer
- export events are often associated to clouds, leading to biases in results derived by combining both types of data
- the simplified approach of selecting data with cloud fraction < 20% instead of detailed cloud treatment leads on average to underestimations of about 20% for an intense hotspot such as Hongkong and less elsewhere

Selected References

Beirle et al., Impact of clouds on tropospheric trace gas retrievals, poster at the NO2 workshop Utrecht, 2007
Boersma, K.F., H.J. Eskes and E.J. Brinksma, Error Analysis for Tropospheric NO2 Retrieval from Space, J. Geophys. Res. 109 D04311, doi:10.1029/2003JD003962, 2004
Boersma, K. F., H. J. Eskes, E. W. Meijer, and H. M. Kelder,, Estimates of lightning NOx production from GOME satellite observations, Atmos. Chem. Phys., 5, 2311 –2331, 2005
Koelemeijer, R. B. A., P. Stammes, J. W. Hovenier, and J. F. de Haan, A fast method for retrieval of cloud parameters using oxygen A band measurements from the Global Ozone Monitoring Experiment, *J. Geophys. Res.* **106**, 3475-3490, 2001
Martin, R. V., K. Chance, D. J. Jacob, T. P. Kurosu, R. J. D. Spurr, E. Bucsela, J. F. Gleason, P. I. Palmer, I. Bey, A. M. Fiore, Q. Li, R. M. Yantosca and R. B. Koelemeijer, An improved retrieval of tropospheric nitrogen dioxide from GOME, J. Geophys. Res, 107, 4437-4456, 2002.
Richter, A. and J. P. Burrows, Retrieval of Tropospheric NO2 from GOME measurements, Adv. Space Res., 29, 16673-1683, 2002.

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