DOAS measurements of NO_2 at Kinshasa and Comparisons with Satellites Observations

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1. Introduction

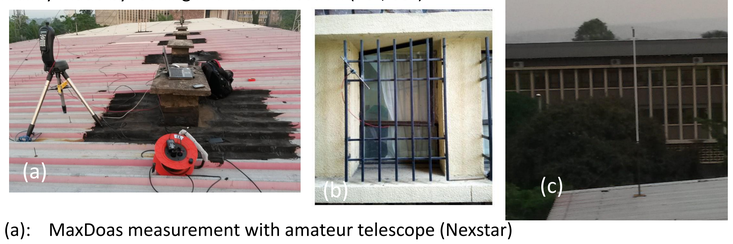
Kinshasa, the capital of the Democratic Republic of Congo is affected by air pollution as shown by several scientific researches and the latest WHO reports [WHO, 2006].

The Royal Belgian Institute of Space Aeronomy (BIRA-IASB) in collaboration with the University of Kinshasa (UniKin), have installed in May 2017 an optical remote sensing instrument on the UniKin site (-4.42°S, 15.31°E). Since then, the instrument has been in operation and provides data to measure the column amounts of several polluting species above Kinshasa.

This poster present the instrument, the database and the procedure used to convert NO_2 slant columns into vertical columns, using the air mass factors calculated with the radiative transfer model. The resulting tropospheric vertical columns could contribute to the validation of satellite products and model refinement. We thus present a first comparison between the Kinshasa observations and the observations from the OMI satellite.

2. The KinAero instrument

The KinAERO instrument was installed above the roof of the Faculty of Sciences of the UniKin. The instrument is based on a compact AVANTES spectrometer covering the spectral range 290 - 450 nm with 0.7 nm resolution. The spectrometer is a Czerny-Turner type with an entry slit of 50 µm wide, and a grating of 1200 l/mm. A 10 m long and 600 µm diameter optical fiber is connected to the spectrometer to receive the incident light beam from the sky. In addition to the measurements in zenith geometry, we also used an amateur telescope (Nexstar) to perform measurements in Multi-axis mode (Honninger et al., 2004). Measurements were mainly made by looking in a fixed direction (90°, 35°).



(a): MaxDoas measurement with amateur telescope (Nexstar)
(b): installation at 35° elevation angle
(c) : zenith geometry installation

3. Observation site

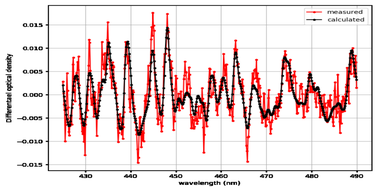
The city of Kinshasa is situated between latitudes 4.17° and 4.22° East and between longitudes 15.14° and 15°32 South, the city of Kinshasa is bounded to the West and North by the Congo River forming the natural border with the Republic of Congo Brazzaville (Fig a).

The sources of pollutants in and around Kinshasa are different from those found in Europe. For example, they include forest fires, open dumps, charcoal for domestic cooking, heavy road traffic, involving a large majority of old vehicles (Fig. b)

4. QDOAS settings

The recorded spectra were analyzed using the QDOAS software. The density of the NO_2 column was recovered in the 425-490 nm spectral region. Absorber cross sections such as NO_2, O_4, O_3, Ring were taken into account. In addition, a fifth degree polynomial was used to account for the contribution of broadband absorption.

Qdoas Settings : see Constantin et al. 2013



fit NO_2 with QDOAS (2017/10/02)
6.90 ± 0.166 (× e16 molecules.cm-2)

5. DSCD to tropospheric VCD conversion

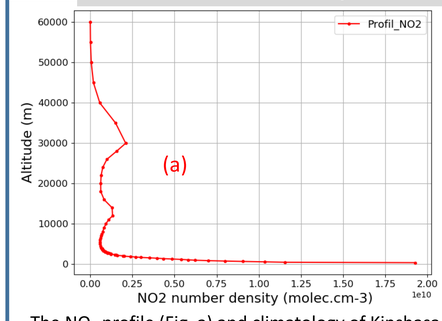
$$VCD_{Tropo} = \frac{DSCD - SCD_{Strato} + SCD_{Ref}}{AMF_{Tropo}}$$

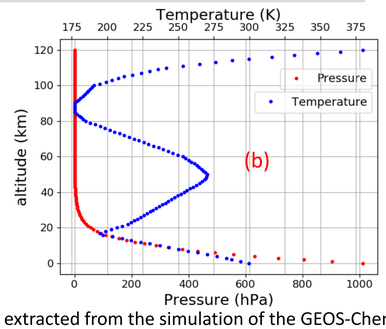
$DSCD$: differential slant column density (obtained from the QDOAS analysis)
SCD_{Strato} :stratospheric component of slant column density
SCD_{Ref}: residual column
AMF_{Tropo}: Tropospheric air mass factor
VCD_{Tropo}: Tropospheric NO_2 column densities

The residual column used for the observations made at the zenith is the one found from MaxDOAS (multi-axis) measurements made on a clear day (2 October 2017), taken at the zenith at 12:14 am in these multi-axis measurements.

For the conversion equation, see: Tack et al 2015

6. A priori Information

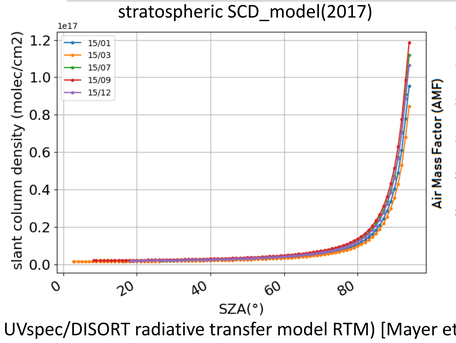


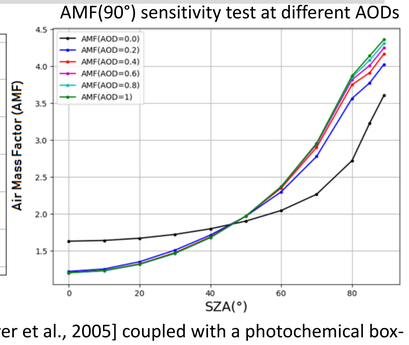


The NO_2 profile (Fig. a) and climatology of Kinshasa , extracted from the simulation of the GEOS-Chem model (v 12.0.2). Data were extracted on a grid of 52 layers of 200 m thick between 1 and 12 km, 9 layers of 200 m thick between 12 and 30 km, and 6 layers of 500 m thick between 30 and 6 km. Our simulation covers the period from 2017 to 2019

The temperature and pressure profiles (Fig. b) used in this work come from global meteorological reanalysis of the European Centre for Medium-Range Weather Forecasts (ECMWF), taken over the 20-year period.

7. components obtained with RTM





UVspec/DISORT radiative transfer model RTM) [Mayer et al., 2005] coupled with a photochemical box-model PSCBOX [Hendrick et al., 2014] was used to calculate the stratospheric column and the VLIDORT[Friedrich et al, 2019] model for the calculation of tropospheric AMF. The NO_2 profile and the climatology as shown in the figures above were used to calculate tropospheric AMF.

Selected References

Honninger et al : Atmos. Chem. Phys., 4, 231–254, 2004
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Friedrich et al: Atmos. Meas. Tech., 12, 2545–2565, 2019
Mayer and Kylling: Atmos. Chem. Phys. 2005, 5, 1855–1877
Hendrick et al : Atmos. Chem. Phys., 14, 765–781, doi:10.5194/acp-14-765-2014, 2014
Tack et al : Atmos. Meas. Tech., 8, 2417–2435, 2015
WHO, 2006 (Air quality guidelines): Rev. Epidemiol. Sante Publique, 51(6), 565–573, 2003
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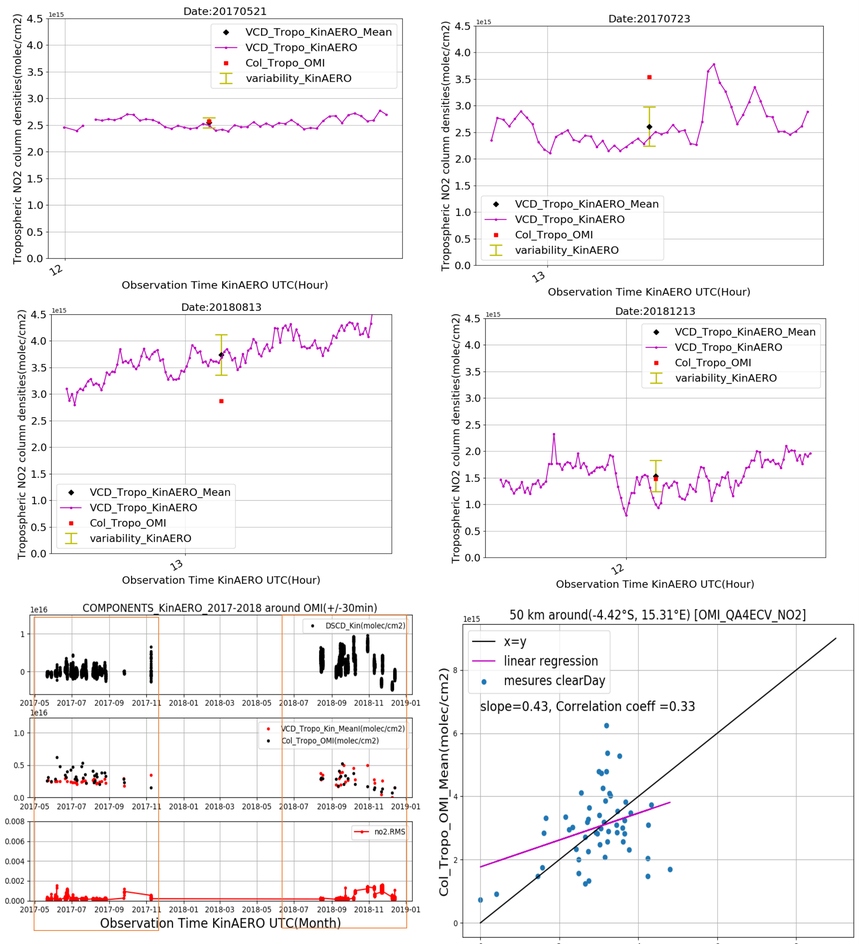
8. Result and comparison

Examples of Tropospheric NO_2 column densities around OMI QA4ECV NO2(+/-30 min)



90° elevation angle observation

35° elevation angle observation

54 days of good ground observations covering the period from May 2017 to March 2018.

No ground observations between November 2017 and July 2018 due to several instrumental issues

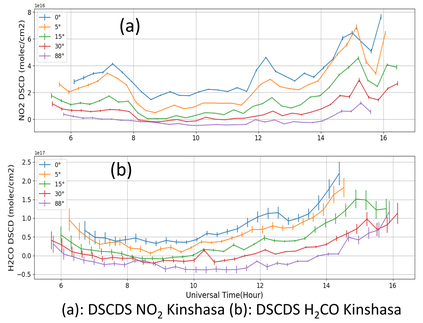
For the OMI product, see : Boersma et al 2018

9. Conclusion & future plans

We have presented in this poster some preliminaries comparisons of tropospheric vertical columns extracted from the one axis measurements (90° and 35°) made in Kinshasa.

The comparisons made over a few days corresponding to the OMI observations give a slope of 0.43. The result of the comparison can be linked to the unknown NO_2 profile in Kinshasa and also to the coarse OMI horizontal resolution. The study will be further extended by exploiting data from the new MaxDOAS instrument installed in Kinshasa since November 2019 (see Fig. a,b) and the use of the GEOS-Chem model and TROPOMI comparison.

MaxDOAS measurements at UniKin on 25 December 2019



(a): DSCDS NO_2 Kinshasa (b): DSCDS H_2CO Kinshasa

We thank Mr DJIBI BUENIMIO for his contribution in the follow-up and maintenance of the KinAERO instrument.