Tropospheric Ozone and Nitrogen Dioxide Measurements in Urban and Rural Regions as Seen by IASI and GOME-2

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1. Introduction

2. Study Area Selection

3. Measurements

4. Results

Volatile Organic Compounds (VOCs)

Nitrogen Oxides (NO$_x$)

Photochemistry

Stratospheric Ozone

Transport

Tropospheric OZONE

Nitrogen Oxides (NO$_x$)

Volatile Organic Compounds (VOCs)

Anthropogenic

Natural

Stratospheric Ozone
Photostationary state: cycling has no net effect on ozone

\[ NO_2 + h\nu \rightarrow NO + O(^3P) \quad \lambda < 424 \text{ nm} \]

\[ O(^3P) + O_2 + M \rightarrow O_3 + M \]

\[ NO + O_3 \rightarrow NO_2 + O_2 \]

An additional pathway is needed to convert NO to NO\textsubscript{2} without destroying O\textsubscript{3}
Photostationary state: cycling has no net effect on ozone

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\[ NO + O_3 \rightarrow NO_2 + O_2 \]

Presence of peroxy radicals, from the oxidation of VOCs (hydrocarbons and aldehydes) disturbs $O_3$-NO-NO$_2$ cycle

\[ NO + RO_2 \rightarrow NO_2 + RO \]

leads to net production of ozone
Measuring tropospheric O$_3$ on a city scale is a challenging task to be accomplished with satellites because of the horizontal and vertical resolution of the instrument.

_Eremenko et al. [2008]_ and _Dufour et al. [2010]_ have shown that it is possible to study, with infrared sounders, the variation of the tropospheric O$_3$ column around cities in particular.
Nine cities in the Northern Hemisphere with high anthropogenic emissions

Study duration: 2008-2011
Nine cities in the Northern Hemisphere with high anthropogenic emissions

**Wind Directions:**
- ECMWF

**Tropospheric O₃:**
- IASI

**Tropospheric NO₂:**
- GOME-2

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Example: Madrid
Wind Analysis

48 Monthly averaged wind direction angles between the surface and 350 hPa blowing from Madrid for the period of 2008-2011.

Wind direction patterns used in this study are from ERA-Interim archive at ECMWF (u- and v-components of horizontal wind).
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Example: Madrid
IASI Ozone Measurements

We chose the 0-8 km column because it provides > 0.5 pieces of information in the troposphere.

Global distributions of O₃ vertical profiles are retrieved in near real time using an exclusive radiative transfer and retrieval software for the IASI O₃ product, the Fast Optimal Retrievals on Layers for IASI (FORLI-O₃) [Hurtmans et al., 2012].
3. Measurements

IASI Ozone Measurements

January 2011

June 2011

0-8 km column of ozone (DU-DAY)
3. Measurements

IASI Ozone Measurements

January 2011

June 2011

Latitude

01/2008

0-8 km ozone column (DU)

2009

2010

2011

15

20

25

30

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GOME-2

- On board of the MetOp-A platform like IASI
- Nadir-scanning UV/visible spectrometer
- Swath width of 1920 km
- Nominal ground pixel size of 80x40 km² (global coverage every 1.5 days)

The operational tropospheric NO₂ product is provided by the German Aerospace center, in the framework of the EUMETSAT O3M-SAF
Seasonal Cycling of Ozone in Urban Regions

1. Introduction  
2. Study Area Selection  
3. Measurements  
4. Results

(a)  
- Mexico City
- Los Angeles
- Istanbul

(b)  
- Madrid
- New York
- Tehran

- New Delhi
- Shanghai
- Beijing

0-8 km O$_3$ column (DU)

Month of the year
Seasonal Cycling of Nitrogen Dioxide in Urban Regions

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Tropospheric O₃ and NO₂ in rural regions
Tropospheric O$_3$ and NO$_2$ in rural regions

$y = 0.40x + 21.12$
$R^2 = 0.35$
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Tropospheric O$_3$ and NO$_2$ in rural regions

4. Results

Tropospheric O$_3$ column (DU) vs. Tropospheric NO$_2$ column x $10^{15}$ (molecules/cm$^2$)

- **Summer 2008-2011**
  - $y = 0.40x + 21.12$
  - $R^2 = 0.35$

- **Winter 2008-2011**
  - $y = 0.08x + 17.49$
  - $R^2 = 0.07$
Beijing Location is indicated with a “+” marker.

Large decrease in NO$_2$, while a no significant decrease for O$_3$.

Large decrease for O$_3$ in the rectangular box in July and September.
Summary and Conclusions

Four years of tropospheric O$_3$ and NO$_2$ observations provided by the IASI and GOME-2 mission are analyzed:

- Consistent seasonal behavior of tropospheric O$_3$, with a peak in spring due to stratospheric intrusion and another higher one in summer due to the photochemical production.
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• NO$_2$ tropospheric column shows a decrease in rural areas due to absence of local sources while rural $O_3$ column persists.
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- Analysis of the Beijing Olympic Games, suggests that even when the concentration of precursors of $O_3$ was well decreased, no significant decrease of tropospheric $O_3$ was observed.
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- This work is thus a new step showing that infrared satellite spectrometers, such as IASI, are capable to track pollution by tropospheric $O_3$ on a city scale and provide relevant information for air quality studies.
Thank you!


For more info please check:
Safieddine et al., 2013 (submitted to JGR)