GOME-2 observations of air quality in Chinese megacities

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Outline

- GOME-2 trace gas column products provided by O3M-SAF
- Ten years trend in key air pollutants in China’s megacities
  - GOME-2 SO₂, NO₂ and HCHO
- Air pollution events in East China in January 2013
- ESA-MOST Dragon 3 project
  - Impact of East Asian Monsoon on air quality over China
- Outlook for Sentinel-4 and -5
Ozone and Atmospheric Chemistry Monitoring SAF

- Part of distributed EUMETSAT ground-segment
- Operational NRT and Off-line products based on GOME-2 and IASI data
- Consortium of ~10 National Meteorological Services and research institutes

Products and services
- Ozone and minor trace gas columns
- Ozone profiles
- Aerosol properties (AAI, AOD, SSA)
- UV products (clear-sky and with clouds/albedo)
- Validation service for each product

- IASI products (O$_3$, SO$_2$, CO, HNO$_3$)
GOME-2 trace gas column products

Near-Real-Time: $O_3$, $NO_2$, $SO_2$

Off-line: $O_3$, $NO_2$, $BrO$, $SO_2$, $H_2CO$, $H_2O$

Megacity and air quality

Megacity: a metropolitan area with a total population of more than 10 million people
- There are 26 megacities in the world, 14 megacities located in Asia and 3 in China
- In China, urban population rate increase from 19.6% to 46% within the last three decades
- Two-thirds of China’s population—an estimated 64%—will live in cities by 2025

Urbanization and industrialization have important consequences for the atmosphere
- Increasing production of harmful pollutants
- Creating significant health problems
- Causing urban and regional haze
- Potential to contribute significantly to climate change

Important to study the anthropogenic impact on atmospheric composition in megacities
Megacities are playing a leading role for regional air pollution problem

<table>
<thead>
<tr>
<th>China's Top 3 City Clusters</th>
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<tbody>
<tr>
<td><strong>Territory</strong></td>
<td><strong>354969 (km²)</strong></td>
<td><strong>3.7 (%)</strong></td>
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<tr>
<td><strong>Population</strong></td>
<td><strong>189.24 (million)</strong></td>
<td><strong>14.1 (%)</strong></td>
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<tr>
<td><strong>GDP</strong></td>
<td><strong>7825.9 (billion)</strong></td>
<td><strong>40.1 (%)</strong></td>
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* Based on data in 2006

The numbers of cars (2010) compared to 2000

Beijing: 4.76 million ~200%
Shanghai: 2.85 million ~100%
Guangzhou: 2.12 million ~170%

More than half year were haze days in Shanghai
Ten years trend of SO$_2$ concentrations

From 2000 to 2005, SO$_2$ showed a clear increase in Shanghai and Guangzhou, due to increase in energy consumption (mainly from coal burning).

After 2007, SO$_2$ showed a relative clear decrease in Beijing, Shanghai and Guangzhou.

<table>
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<tr>
<th>PJ</th>
<th>2000</th>
<th>2005</th>
<th>Increase</th>
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<tbody>
<tr>
<td>Industry coal use</td>
<td>10,178</td>
<td>17,053</td>
<td>68%</td>
</tr>
<tr>
<td>Electricity coal use</td>
<td>12,203</td>
<td>24,028</td>
<td>97%</td>
</tr>
<tr>
<td>On road transport</td>
<td>1,946</td>
<td>3,424</td>
<td>76%</td>
</tr>
<tr>
<td>Off road transport</td>
<td>1,387</td>
<td>2,696</td>
<td>94%</td>
</tr>
</tbody>
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SO$_2$ data from EPA

Satellite observation of $SO_2$ over China

2008

GOME-2

SO2 column density [DU]

Beijing

Shanghai

Guangzhou
Comparison with in-situ $\text{SO}_2$ measurement in Shanghai

In-situ $\text{SO}_2$ data from Shanghai EPB
Ten years trend of NO\textsubscript{2} concentrations

NO\textsubscript{2} showed no evident annual trend in Shanghai.

From 2004, NO\textsubscript{2} showed a decreasing trend in Guangzhou.

In 2008, NO\textsubscript{2} showed a clear decrease in Beijing, but increase again after 2008.
GOME-2 Tropospheric NO$_2$ over China (2007-2012)

A significant increase of NO$_2$ over China from 1994 to 2006 observed by GOME and SCIAMACHY

Van der A et al., J. Geophys. Res., 2006

Monthly means MAX-DOAS and GOME-2 tropospheric NO$_2$ over Shanghai and Wujiang

GOME-2: mean values of all the pixels within 50 km around Wujiang and Fudan University
GOME-2 Tropospheric HCHO over China (2007-2012)

HCHO/NO$_2$ column ratio:
Indicator of surface ozone-NO$_x$-VOC sensitivity
Beijing, Shanghai and Guangzhou: VOC-limited

GOME and SCIAMACHY HCHO for 1997-2009
Growth rate: 4 ± 1.4% per year
De Smedt et al., 2010
Air Pollution Events in East China in mid-January 2013

Beijing Air Quality Index (AQI)

One of the worst period of air quality in Beijing and other cities in China

Peak of AQI is 775 on Jan. 12 – off the US. Environmental Protection Agency scale
Beijing Olympic Stadium
Jan. 14, 2013

MODIS Jan. 14, 2013
Trop. NO2 over Beijing in January 2011-2013

GOME-2 Trop. NO2 over Beijing (100km)

- 2013
- 2012
- 2011
Assessment of the impact of the East Asian Summer Monsoon on the air quality over China

Dr 3 project Id. Number 10455

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Background and Objectives

Provide a holistic view of the monsoon impact on tropospheric ozone and related trace gases over China.

Monsoon climate controls air pollution transport in East Asia, especially for “long-life” species like O3.
Summary of Expected Results

- A comprehensive databank of ozone and related trace gases from various platforms

- Improved understandings of the driving mechanisms of the seasonal patterns and inter-annual variations of air pollution in different regions of China.

- A general assessment on the uncertainties of satellite products and improved retrieval algorithms of some species in the high-polluted East Asian regions
Outlook for Sentinel-4 and -5

DLR has a strong interest in S4-UVN and S5-UVNS product development and processing.

Strong involvement in GOME/ERS-2, SCIAMACHY, GOME-2/MetOp and S5P.
- Processor development
  - Level-1 and Level-2 processors
  - Prototype and operational
- Operational processing
  - Part of (distributed) ground-segment (ESA and EUMETSAT)

Sentinel-4/UVN
- Level-1b prototype processor development ongoing
- Level-2 prototype processors (ESA-ITT in 2013?)
- Operational processors and processing
  - Central or distributed EUMETSAT ground-segment ???

Sentinel-5/UVNS
- Prototype Level-1b and Level-2 processor development ???
- Operational processors and processing ???
Conclusions

Ten years trend in key air pollutants in Chinese megacities
- SO\textsubscript{2} emissions successfully controlled from 2007 to 2010, increase in Beijing after 2010
- NO\textsubscript{2} showed a decreasing trend in Guangzhou, but not in Beijing and Shanghai
- Particulate pollution especially PM\textsubscript{2.5} is the major air pollution problem

MAXDOAS measurements in Shanghai from 2010 until now
- Preliminary comparison results show good agreement between satellite and ground-based measurements

Satellite observations can be used to monitor air quality in mega-cities

Operational GOME-2 trace-gas products available at:

http://atmos.caf.dlr.de/gome2