FICHE : Bilateral BEL-China R&D cooperation - BL /35/60

IBBAC

(Impact of Biogenic Emissions on Beijing Air Quality and Climate)

Project title : Impact of Biogenic Emissions on Beijing Air Quality and Climate

Study area : Beijing, People's Republic of China

Context and objectives

Due to its high population and rapid economic growth, Beijing ranks among the most polluted cities worldwide. Besides the rising demand for reliable anthropogenic emission estimates reflecting the current air pollution situation, the estimation of emissions from the biosphere and their effects on air pollution is very important for addressing environmental issues such as air quality degradation, and warming climate in the context of the delicate balance between economic prosperity and environmental concerns. The aim of the IBBAC project is to evaluate the role and impacts of biogenic VOC (volatile organic compounds) emissions on summertime air pollution levels in Beijing and surrounding areas. Among the biogenic VOC, isoprene is the most largely emitted and is therefore a primary focus of this work. The project relies on the long-standing expertise acquired at BIRA-IASB, VITO and IAP in (i) high quality atmospheric MAX-DOAS measurements of air pollutants, (ii) development of biogenic emission models, (ii) advanced inverse modelling tools, (iii) satellite remote sensing data, (iv) statistical downscaling techniques, and (v) numerical atmospheric composition modelling.

To achieve the project goals, we first derive improved estimates of isoprene emissions in China based on bottom-up and top-down techniques, and use statistical downscaling to obtain high-resolution emission fields in the vicinity of Beijing. Further, we use the global tropospheric model IMAGES developed at BIRA-IASB, and the AURORA high-resolution air quality model developed at VITO to compare with ground-based measurements of air pollutants obtained at the Beijing region by a MAX-DOAS instrument thanks to the successful collaboration between BIRA-IASB and the Chinese partner. Finally, we study the model sensitivity of key air quality markers to climate perturbations through their impact on biogenic emissions and the subsequent changes in air pollutant concentrations (e.g. surface ozone) in the broader Beijing area.

Methodology

WP1:

- Derivation of a historical (1970-2010) biogenic emission record for China based on MEGAN emission model and ECMWF meteorology. This long-term record serves to determine a year with exceptionally hot summer, which will be considered as a reference for a "climate change" case

- Improved representation in the IMAGESv2 of biogenic and anthropogenic VOCs, based on recent speciation data for anthropogenic VOCs and developments in the atmospheric degradation of isoprene

- Derivation of improved emission estimates for anthropogenic and biogenic reactive VOCs using IMAGESv2 in an inversion exercise constrained by satellite HCHO columns

- Implementation of the top-down biogenic emissions in the AURORA/VITO model

- Use of downscaling techniques that spatially disaggregate coarse emissions to a fine grid

WP2:

- Use of ground-based MAX-DOAS measurements of air pollutants at downtown Beijing and at Xianghe sites to validate the AURORA/VITO and IMAGESv2/BIRA-IASB model output

- Use of boundary conditions from IMAGESv2 in AURORA/VITO model

- Base case simulations with AURORA for the agglomeration of Beijing at high resolution, and with IMAGESv2 at a coarse resolution to serve as reference for evaluating the impact of biogenic emissions. Comparison of simulated concentrations with observed values provided by ground-based observations

- Evaluation of the impact of biogenic emission changes on pollutant concentrations in Beijing and its vicinity to be carried out using AURORA and IMAGES model

Scientific Results

WP1

We have investigated the interannual variability of isoprene emissions in China between 1979 and 2012, using the MEGAN-MOHYCAN emission model. Changes in isoprene emissions induced by the warming climate, changes in solar radiation, and the conversion of primary forests to croplands have been explored. Temperature, solar radiation and soil moisture are driving the interannual variability. The average warming trend over China (0.3◦C per decade) is the primary cause for the calculated increase in isoprene emissions, estimated at 0.52% per year, whereas crop abandonment and solar brightening are found to reinforce the emission trend (0.72%yr). In the Beijing area, the emission trend is equal to 0.7% per year over 1979-2012, mostly due to the warming climate.

Using satellite columns of HCHO and advanced inverse modelling tools, we have derived top-down anthropogenic and biomass burning emission estimates. We showed that fire emissions in the North China Plain in June related to harvest season burning is an important source of pollution competing with the emissions from the industrial and transport sector. This emission source is currently neglected in atmospheric models but is crucial in order to redefine agriculture management practices in this region.

WP2

MAX-DOAS UV-Visible measurements of key pollutants (NO_2, HCHO, SO_2, HONO and aerosols) were performed at downtown Beijing and at the suburban site of Xianghe in collaboration between BIRA-IASB and IAP. These measurements, complemented by satellite observations, were used to evaluate the model performances for a reference year (2008) and a "climate-change" year, chosen here to be the exceptionally warm 2007. The use of either the coarse IMAGESv2/BIRA-IASB or the fine resolution AURORA/VITO model to calculate the atmospheric composition in the vicinity of Beijing, leads to qualitatively similar conclusions. More specifically, warmer temperatures and consequently higher biogenic isoprene emissions are found to cause substantial increase in the simulated surface ozone summertime concentrations, by up to around 20 $\mu g/m^3$, as a result of the very high nitrogen oxides concentrations in the area. This result demonstrates the importance of biogenic emissions and the need for their accurate quantification in order to guide policy making aiming at the mitigation of air quality in this region. We recommend to enhance collaboration with Chinese scientists in order to confirm the important role of biogenic VOC by means of in situ measurements and further modelling activities.

Products and services

IBBAC website : http://tropo.aeronomie.be/ibbac

International conference proceedings:

1. De Smedt, M. Van Roozendael, T. Stavrakou, J.-F. Müller, *Intercomparison of five years of global formaldehyde observations from the GOME-2 and OMI sensors*, Proceedings of the ESA Atmospheric Science Conference, Advances in Atmospheric Science and Applications, Bruges, June 2012.

2. Bauwens, M. J.-F. Müller, T. Stavrakou, J.-F. Müller, I. De Smedt, and M. Van Roozendael, *Satellite-based isoprene emission estimates (2007-2012) from the GlobEmission project*, Proceedings of the ACCENT-Plus Symposium, Atmospheric Composition Change - Policy Support and Science, Urbino, 17-20 September, 2013.

Peer-reviewed articles in preparation or published:

Published

1. De Smedt, I., M. Van Roozendael, T. Stavrakou, J.-F. Müller, C. Lerot, N. Theys, P. Valks, N. Hao, and R. van der A, *Improved retrieval of global tropospheric formaldehyde columns from GOME-2/MetOp-A addressing noise reduction and instrumental degradation issues*, Atmos. Meas. Tech., 5, 2933-2949, 2012.

2. Hendrick, F., J.-F. Müller, K. Clémer, P. Wang, M. De Mazière, C. Fayt, C. Gielen, C. Hermans, J. Z. Ma, G. Pinardi, T. Stavrakou, T. Vlemmix, and M. Van Roozendael, *Four years of ground-based MAX-DOAS observations of HONO and NO_2 in the Beijing area*, Atmos. Chem. Phys., 14, 765-781, 2014.

3. Müller, J.-F., J. Peeters, and T. Stavrakou, *Fast photolysis of carbonyl nitrates from isoprene*, Atmos. Chem. Phys., 14, 2497-2508, 2014.

4. Stavrakou, T., J.-F. Müller, K-F. Boersma, R.J. van der A, J. Kurokawa, T. Ohara, and Q. Zhang, *Key chemical NOx sink uncertainties and how they influence top-down emissions of nitrogen oxides*, Atmos. Chem. Phys. 13, 9057-9082, 2013.

5. Stavrakou, T., J.-F. Müller, A. Guenther, M. Bauwens, I. De Smedt, M. Van Roozendael, A. Guenther, M. Wild, and X. Xia, *Isoprene emissions in Asia over 1979-2012 : impact of climate and land use changes*, accepted in Atmos. Chem. Phys. 2014.

6. Wang, T., F. Hendrick, P. Wang, G. Tang, K. Clémer, H. Yu, C. Fayt, C. Hermans, C. Gielen, G. Pinardi, N. Theys, H. Brenot, and M. Van Roozendael, *Evaluation of tropospheric SO_2 retrieved from MAX-DOAS measurements in Xianghe, China*, Atmos. Chem. Phys. Discuss., 14, 6501-6536, 2014.

In preparation :

1. De Smedt, I., T. Stavrakou, T. Danckaert, N. Theys, C. Lerot, J.-F. Müller and M. Van Roozendael, *Satellite observation of tropospheric formaldehyde combining GOME-2 and OMI measurements*, to be submitted to Atm. Meas. Tech., 2014.

2. Gielen, C., M. Van Roozendael, F. Hendrick, C. Fayt, C. Hermans, G. Pinardi, T. Vlemmix, D. Gillotay, V. De Bock, and H. De Backer, *The impact of cloud screening in MAX-DOAS aerosol retrievals*, to be submitted in Atmos. Meas. Tech., 2014.

3. Vlemmix, T., F. Hendrick, G. Pinardi, I. De Smedt, C. Fayt, C. Hermans, P. Levelt, and M. Van Roozendael, *MAX-DOAS observations of aerosols, formaldehyde and nitrogen dioxide in the Beijing area: comparison of two profile retrieval approaches*, to be submitted in Atmos. Chem. Phys., 2014.

- Others

La qualité de l'air surveillée depuis l'espace/Monitoring van luchtkwaliteit vanuit de ruimte, Science Connection, 42, p. 34-35, 2014.

EC cooperations generated by the projects

Participation of BIRA-IASB and VITO in the Collaborative project FP7-EC606953 "*Monitoring and Assessment of Regional air quality in China using space Observations, Project of Long-term sino-european Co-operation*- MARCOPOLO (Jan 2014-Dec 2016)

Ideas for future research

Our findings point out the importance of biogenic emissions and the need for their accurate quantification in order to guide policy making aiming at the mitigation of air quality in Beijing region. It is therefore recommended to enhance collaboration with Chinese scientists in order to confirm the important role of biogenic VOC by means of in situ measurements and further modelling activities.

In addition, we demonstrated the added value from the use of satellite measurements as top-down constraints by quantifying the source from crop residue burning in the North China Plain, one of the most densely populated area on Earth. This source was found to be by a factor of 2-3 higher than previously estimated and should be taken into account in order to redefine agriculture management practices in this region. Ground-based measurements in the North China Plain would therefore be highly desirable.

Execution

Period: November 2011 – December 2013

Laboratory/network (promotor names, institutes, mail-adresses, web-site) :

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Discipline

Air quality and climate, biogenic emissions, atmospheric modelling