Press Releases

January 27, 2017
JAMSTEC
Nagoya University

World's First Estimation of Long-term Variations in Global Atmospheric Pollutant Emissions based on Data Assimilation
- Rapid increases over India and large variations over China -

1. Overview

A research team led by Dr. Kazuyuki Miyazaki at Department of Environmental Geochemical Cycle Research, the Japan Agency for Marine-Earth Science and Technology (JAMSTEC: Asahiko Taira, President) has found large variations in surface emissions of nitrogen oxides (NOx)[*i] worldwide in recent years by using satellite observations and data assimilation[*ii], a mathematical statistical approach. This work was carried out in collaboration with NASA and Nagoya University.

Because NOx is emitted from the Earth’s surface and then face losses through chemical reactions in the atmosphere, atmospheric concentrations vary widely, making it difficult to estimate emission sources based on these concentration measurements. Existing estimation methods do not entirely account for the effect of losses, resulting in large uncertainties in the estimated emissions. The research team has developed a system to estimate surface emissions based on data assimilation by comparing satellite observations of various chemical species in the atmosphere with the simulation results from the chemical transport model CHASER[*iii], while taking the effect of losses into account.

The estimation results showed that, on average, during the 10-year period of 2005-2014, there was a large increase in NOx emissions over India (+29%) and the Middle East (+20%), whilst emissions decreased over the United States (-38%), West Europe (-9%) and Japan (around Tokyo and Osaka:-30–50%). The emissions decreased significantly over the major developed countries, possibly reflecting the effects of emission regulations and economic recession following the financial crisis. The emissions increased over China from 2005 to 2011 by more than 30%, but after 2011 started to decrease mainly in three major cities (Beijing, Shanghai and Guangzhou). Many results here differ from those obtained with previous estimation methods.

This study clarifies long-term variations in emissions differing by region. Using the estimated emissions, the research team succeeded in reproducing variations in ozone, a chemical product of NOx, as well as NOx. The residence time of ozone is longer than that of NOx in the lower atmosphere, and NOx variation information can be clearly seen in ozone distributions. The ozone validation results thus suggest a reduced uncertainty of NOx emissions in comparison with the results of conventional estimation methods. Further, our approach provides the first emission estimation for the entire globe. Based on the globally consistent estimate, we found, for instance, that the regional total emissions are comparable between India and the whole Europe in 2014.

These results are useful for confirming whether emission controls in developed nations have been effective and also establishing emission regulations in developing nations. NOx influences the amount of greenhouse gases, photochemical oxidants, and PM2.5. Therefore, the obtained results can also be used for improving the accuracy of PM2.5 forecasts and for making policies related to health, agriculture, and global warming. Also, the globally consistent data can be used to contribute to discussions on climate change by the Intergovernmental Panel on Climate Change (IPCC).

This study was supported by Coordination Funds for Promoting AeroSpace Utilization by the Ministry of Education, Culture, Sports, Science and Technology in Japan.

The above results were published in the European Geosciences Union journal, "*Atmospheric Chemistry and Physics*" on January 27, 2017 (JST).

Title: Decadal changes in global surface NOx emissions from multi-constituent satellite data assimilation
Authors: Kazuyuki Miyazaki[1,2], Henk Eskes[3], Kengo Sudo[4,1], K. Forkert Boersma[3], Kevin Bowman[2], Yugo Kanaya[1]
Affiliations:[1]JAMSTEC, [2]NASA, [3]Royal Netherlands Meteorological Institute (KNMI),[4]Graduate School of Environmental Studies, Nagoya University

*i Nitrogen oxides: Generic name of nitrogen and oxygen compounds, mainly nitrogen monoxide (NO) and nitrogen dioxide (NO2), generally called NOx. They are major air pollutants and adversely affect human health and agricultural products by forming photochemical oxidants and PM2.5. They also affect the amount of greenhouse gases, such as methane, and therefore play an important role in climate change. Sources that emit nitrogen oxides include those originating from human activity, such as vehicles, industries, and thermal power plants, in addition to natural sources such as biomass burning, soil, and lightning.

*ii Data assimilation: A method to adjust simulation results from numerical models based on actual observation data. This method is also used for weather forecasts; for instance, to infer the most plausible atmospheric conditions. It is also used to derive estimations of emissions from observed concentration information, as was done in this study.

*iii Chemical transport model CHASER: A simulation model developed in Japan mainly by the Nagoya University and JAMSTEC to calculate and reproduce the three-dimensional distribution of substance concentrations in the atmosphere, and their temporal changes. The effect of production and loss through chemical processes and the effect of atmospheric transport due to wind are calculated using given emissions, reproducing the concentration distributions of various atmospheric substances.

Cities and regions with large increase rates	Cities and regions with large decrease rates

Northwestern China (China)	+110 %	Chicago (United States)	-50 to -60 %
Raipur (India)	+60 to +70 %	Northeastern France (France)	
Chengdu (China)	+50 to +60 %	Po Valley (Italy)	
Kuwait (Kuwait)	+40 to +50 %	Tokyo (Japan)	-40 to -50 %
Calcutta (India)		New York (United States)	
Wuhan (China)		Atlanta (United States)	
Sao Paolo (Brazil)		Los Angeles (United States)	
Chennai (India)		Northern Spain (Spain)	
Tehran (Iran)	+30 to +40 %	Boston (America)	
Nanjing (China)		Osaka (Japan)	-30 to -40 %

Table 1 Increase and decrease rates in nitrogen oxide emissions for the 10 top-ranking cities and regions (country name in brackets) between 2005 to 2014. Estimates are based on a 300 km square scale and the table shows the names of representative cities within the analysed regions.

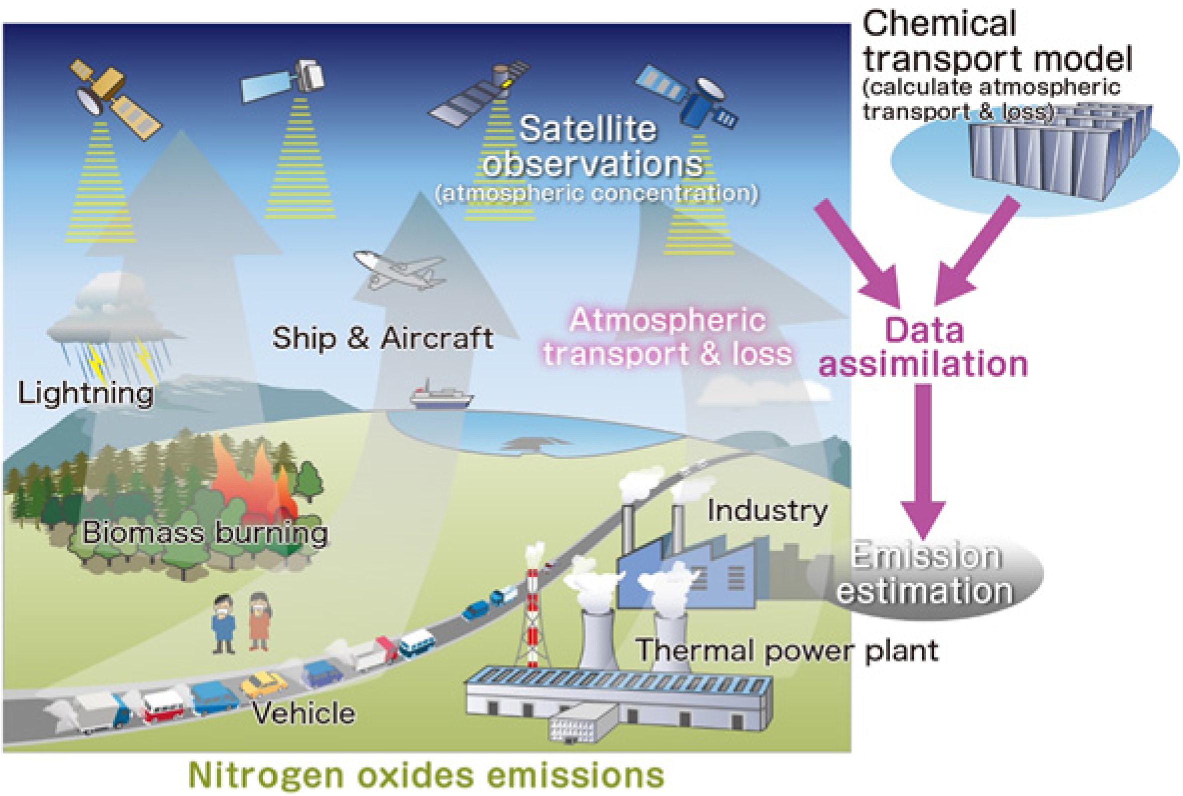

Figure 1: A conceptual diagram showing the method for nitrogen oxide (NOx) emission estimation. NOx are emitted from sources related to human activity such as vehicles, industries, and thermal power plants, and additionally from natural sources such as biomass burning, soil, and lightning, from the surface of the earth into the atmosphere. In the atmosphere they are transported by winds and face losses due to chemical reactions. Satellite instruments observe NOx concentrations in the atmosphere. Data assimilation combines information obtained from the satellite measurements and chemical transport model simulations, which provides an optimal value of surface NOx emission while considering the influence of atmospheric transport and losses.

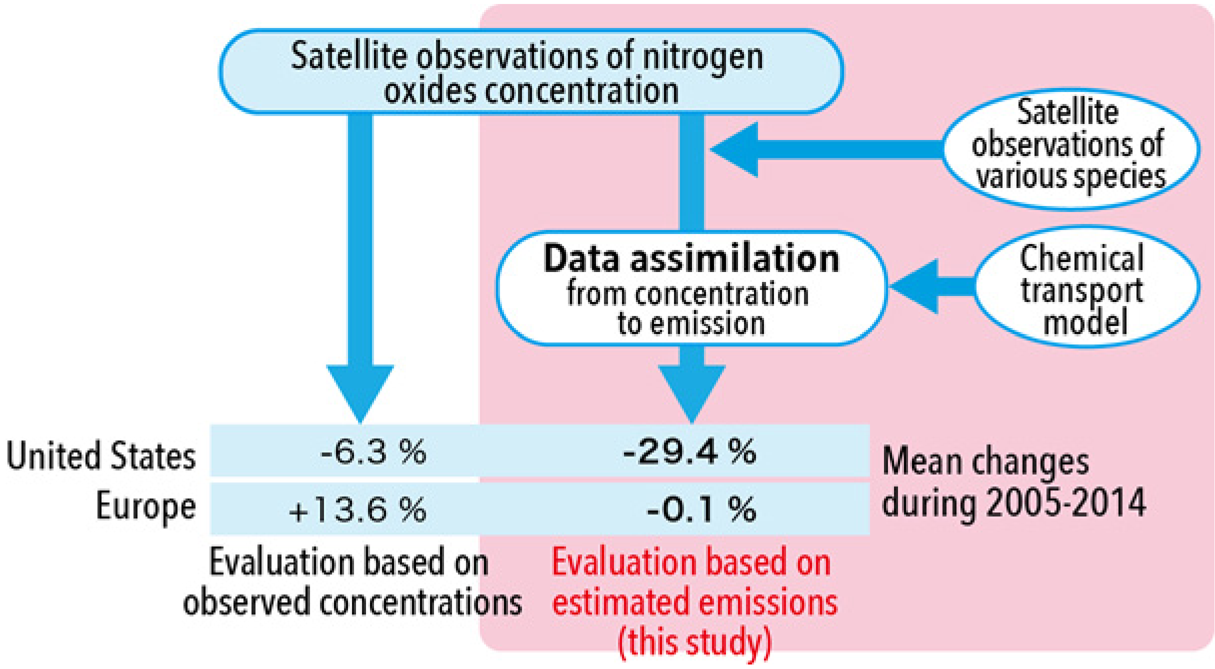

Figure 2. Comparison of NOx emission estimation methods. The example shows the mean changes (in percent) for the United States and Europe for the 10-year period from 2005 to 2014. The figure shows evaluation results directly using observed concentrations of nitrogen oxides (left), and evaluation results of this study using emission estimates of various species obtained through data assimilation (right).

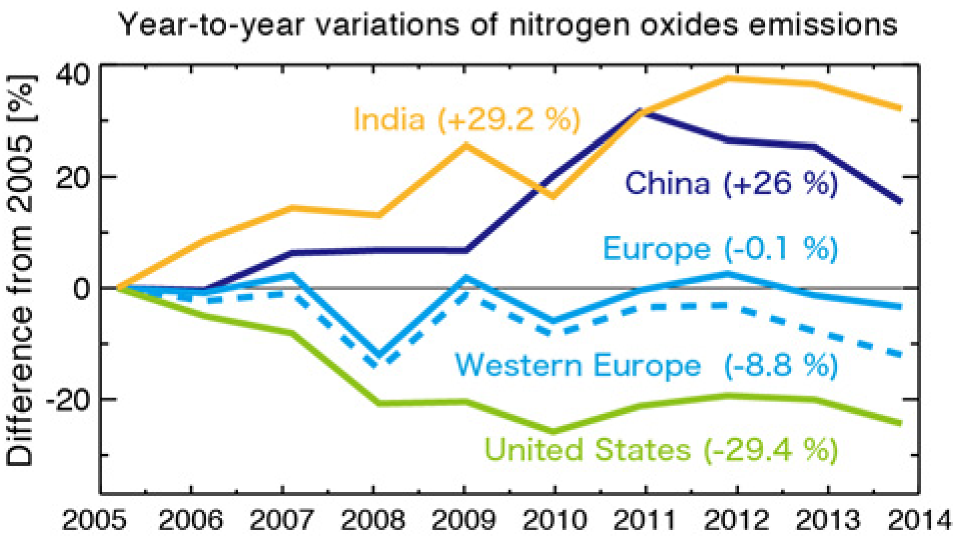

Figure 3. Variations in NOx emissions for major regions of the world. Differences from 2005 are shown in percent. The values in brackets show the average variations over the 10-year period from 2005 to 2014.

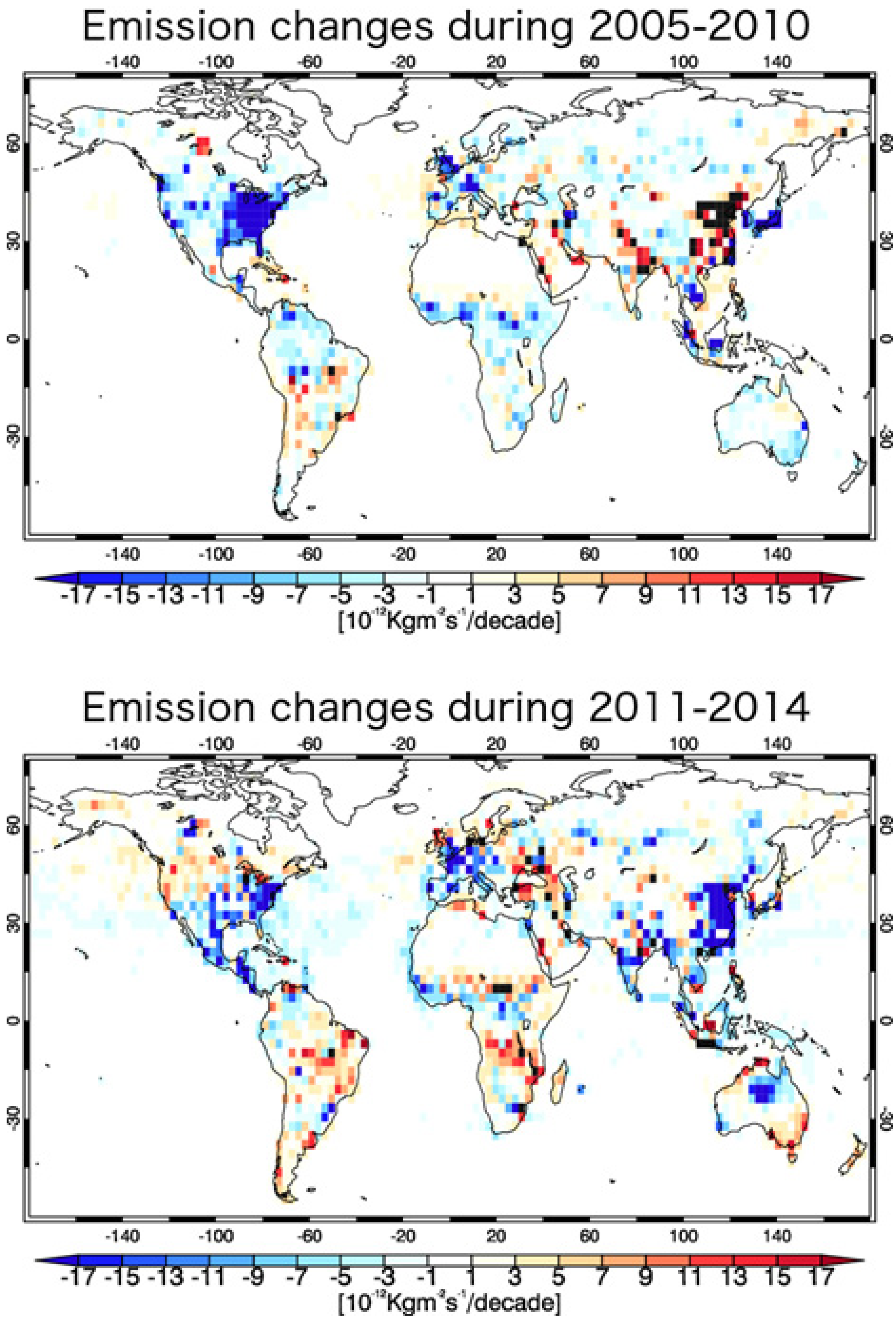

Figure 4. Global distribution of the average changes in NOx emissions from 2005 to 2010 (top) and from 2011 to 2014 (bottom). Red represents increase, and blue indicates decrease, with deeper colours representing greater variations.

Contacts:

(For this study)

Kazuyuki Miyazaki, Senior Scientist, Department of Environmental Geochemical Cycle Research/Research and Development Center for Global Change, JAMSTEC

Yugo Kanaya, Deputy Director, Department of Environmental Geochemical Cycle Research, JAMSTEC

Kengo Sudo, Associate Professor, Graduate School of Environmental Studies, Nagoya University

(For press release)

Tsuyoshi Noguchi, Manager, Press Division, Public Relations, JAMSTEC

Jun Okubo, Assistant manager, Public information, Public Relations Section, General Affairs Dept., Nagoya University