Emisat: Satellite-Based High-Resolution NOx Emission Reporting for CSRD Compliance

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Abstract

This study evaluates the feasibility of Emisat's proposed service for high-resolution NOx emission reporting using satellite data. The service aims to provide accurate, timely, and cost-effective emissions data to assist companies in complying with the EU's Corporate Sustainability Reporting Directive (CSRD). Our analysis indicates that the proposed service is technically feasible and has significant market potential, although some challenges remain to be addressed.

The core of our approach leverages the methodology described by Beirle et al. (2019) (1), which combines NO2 column measurements from the TROPOMI instrument on the Sentinel-5P satellite with wind field data to calculate NOx fluxes and their divergence. This method allows for the identification and quantification of emissions from individual point sources with high spatial resolution. We plan to extend this approach by incorporating machine learning techniques to improve accuracy and overcome some of the limitations of the baseline method.

Additionally, our service aims to track NOx emissions over short distances and evaluate their impact on neighboring communities, enabling more targeted environmental management strategies.

1 Business Case

The primary target market for Emisat's service encompasses a range of stakeholders affected by the Corporate Sustainability Reporting Directive (CSRD, see (2)). The CSRD, adopted by the European Union, significantly expands the scope of sustainability reporting requirements for companies operating within the EU. It mandates comprehensive disclosure of environmental, social, and governance (ESG) impacts, with a particular focus on how company activities affect climate change, pollution, and human rights.

Approximately 50,000 companies across the EU will be subject to CSRD reporting requirements. These organizations form the core of our target market, as they will need reliable, cost-effective methods to measure and report their environmental impacts, including NOx emissions. Additionally, our service will be valuable to environmental consultancies that assist these companies in achieving CSRD compliance. These consultancies can integrate our emission data into their broader sustainability reporting services, enhancing the value they provide to their clients. Government agencies responsible for emissions monitoring and regulation enforcement represent another key market segment. Our service can provide these agencies with an independent, objective source of emissions data, potentially aiding in the detection of fraudulent reporting or non-compliance with environmental regulations.

Emisat's service offers several compelling advantages over traditional emissions monitoring methods. By leveraging satellite-based monitoring, we eliminate the need for extensive and costly ground-based sensor networks. This approach enables wide coverage, allowing us to monitor emissions across large geographic areas, including remote or inaccessible locations where traditional monitoring would be impractical or prohibitively expensive. The near-daily global coverage provided by the TROPOMI instrument allows for frequent updates and timely emission tracking. This temporal resolution is particularly valuable for identifying short-term emission events or tracking the effectiveness of emission reduction measures.

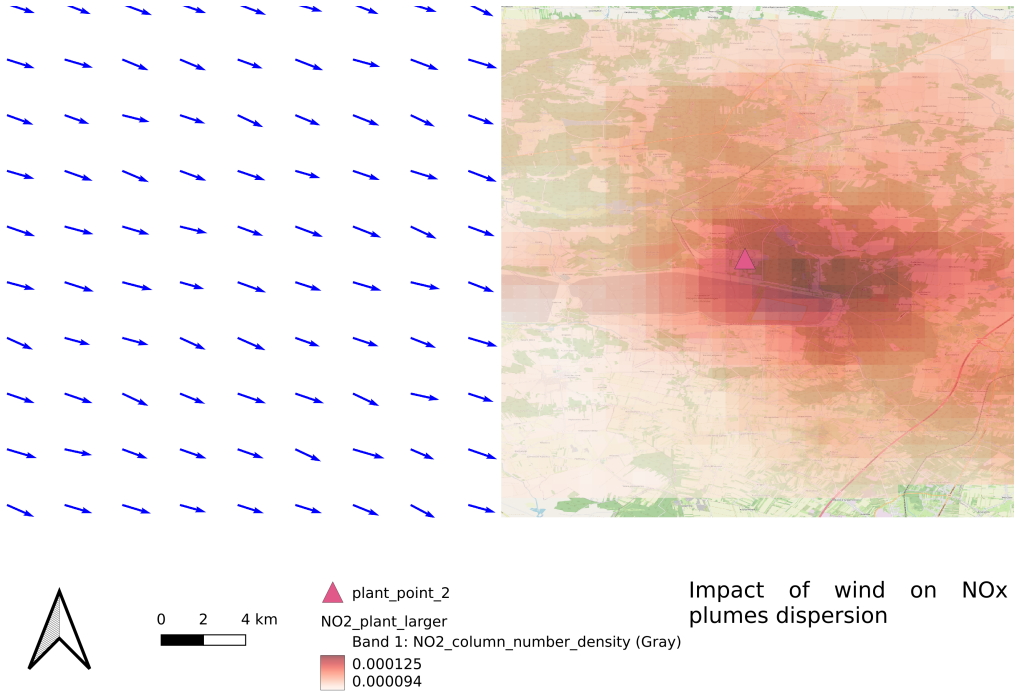
2 Baseline Product

The foundation of Emisat's service is built upon the methodology described by Beirle et al. (1) for deriving high-resolution NOx emission maps from satellite observations. This approach combines NO2 column measurements from Sentinel-5P satellite with wind field data to calculate NOx fluxes and their divergence. Sentinel-5P provides NO2 tropospheric column data with a spatial resolution of 3.5 x 7 km2. This data is then combined with wind field data from the European Centre for Medium-Range Weather Forecasts (ECMWF). By calculating the

divergence of horizontal NOx fluxes, we can identify and locate point sources of emissions with remarkable precision.

To quantify emissions from individual sources, we employ an iterative peak fitting algorithm. This algorithm allows us to distinguish between diffuse urban pollution and concentrated emissions from specific industrial facilities or power plants. The proposed methodology has been tested and demonstrated to be effective in peer-reviewed research and has been replicated in the east asian context (see (3)). Beirle et al. successfully applied this method to identify and quantify emissions from power plants and other point sources in multiple regions, including Saudi Arabia, South Africa, and Germany. The high spatial resolution of Sentinel-5P data enables the detection of individual industrial facilities, a crucial capability for providing actionable insights to our clients.

However, we acknowledge that there are technical challenges that need to be addressed. In areas with high urban background pollution, isolating emissions from individual sources can be more challenging. We estimate our target resolution to be 2km, which should allow us to pollution sources from relatively isolated industrial or agricultural sources. Validation remains a critical challenge. To ensure the reliability and accuracy of our satellite-derived emissions data, we will need to gather and use ground-truth data for calibration and ongoing validation of our model.



To validate and refine our approach, we are currently replicating the study using the Bełchatów Power Station in Poland as our primary use case (see figure **??**). This facility, also known as Elektrownia Bełchatów, is the largest thermal power station in Europe and one of the world's largest coal-fired power plants. Its significant emissions and relative isolation from major urban centers make it an ideal candidate for our initial analysis. For this use case, we are using data sources available through Google Earth Engine. Specifically, we are using Sentinel-5P TROPOMI NOx data for measuring NOx concentrations. For wind direction and speed data, we are using the Global Forecast System (GFS), which provides high-resolution global weather forecast data (see figure 1 for model correction).

3 Product roadmap

We aim to develop a robust ground-truth dataset of emissions using on-site measurement data. We plan to leverage data from the European Pollutant Release and Transfer Register (E-PRTR) for this purpose. The E-PRTR is a Europe-wide register that provides easily accessible key environmental data from industrial facilities in European Union Member States and in Iceland, Liechtenstein, Norway, Serbia, and Switzerland. It contains annual data reported by more than 30,000 industrial facilities covering 65 economic activities across Europe.

Using this ground-truth data, we aim to develop a machine learning model that will use our baseline model as input, along with additional relevant data sources. These additional sources may include atmospheric data

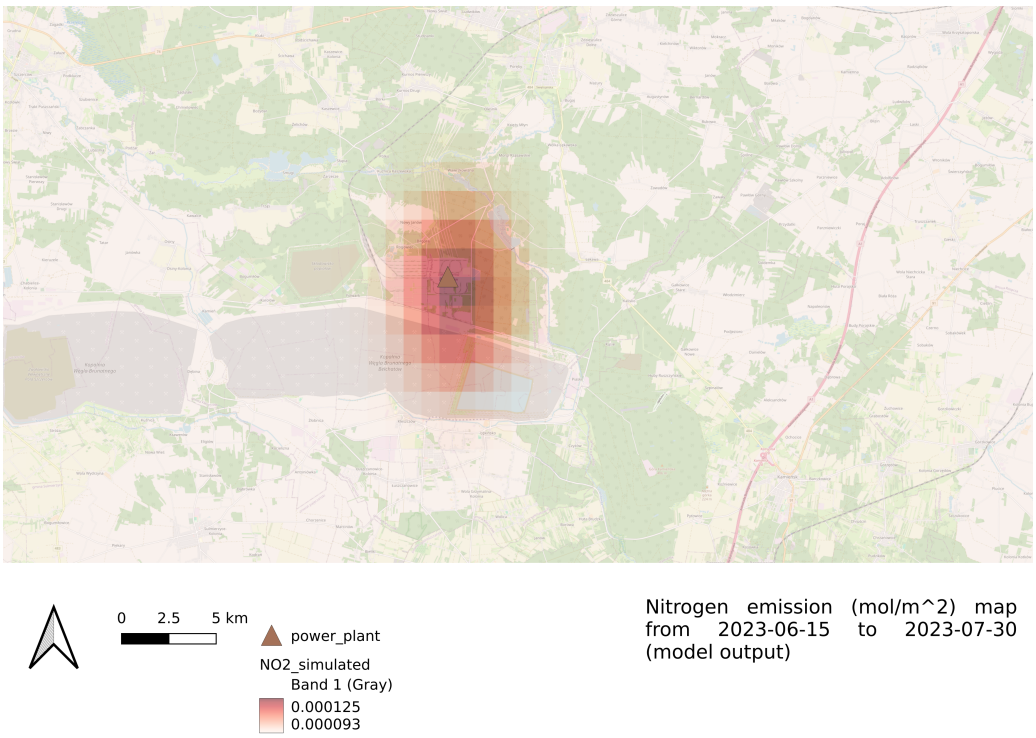


Figure 1: NOx emission after model correction.

(such as temperature, pressure, and humidity profiles), RGB satellite imagery of emission sites, and tabular data on the type and characteristics of each emission source. We will go through a process of feature selection to identify the most relevant data sources for an enhanced predictive model. By incorporating these diverse data sources and leveraging advanced machine learning techniques, we expect to reduce the accuracy error of our emission estimates.

A key innovation in our product roadmap is the development of capabilities to track NOx emissions over short distances and evaluate their impact on neighboring communities. This feature will make companies more accountable for their environmental impact and open up new possibilities for targeted emission reduction strategies. From a regulatory perspective, it could inform more effective pollution control policies. For companies, it provides opportunities for enhanced corporate social responsibility initiatives, such as partnering with local organizations to implement compensatory measures in affected areas. This capability could drive new business models, including emissions trading or offset programs that directly benefit affected communities. Companies could use our impact assessments to develop partnerships for local renewable energy projects, energy efficiency improvements, or reforestation efforts in the region.

A critical aspect of our product roadmap is achieving regulatory acceptance. Emisat will need to work closely with regulatory bodies to ensure our methodology is accepted for compliance reporting under the CSRD and other relevant environmental regulations. This will involve ongoing dialogue with regulators, participation in relevant industry working groups, and potentially undertaking pilot studies or certification processes to demonstrate the reliability and accuracy of our emission estimates.

As we refine our model and expand our capabilities, we envision broadening our service to include other pollutants beyond NOx, such as methane and CO2. This expansion will increase the value we provide to our clients and position Emisat as a comprehensive provider of satellite-based emission monitoring services.

References

[1] Beirle, S. *et al.* Pinpointing nitrogen oxide emissions from space **5**.

[2] DIRECTIVE (EU) 2022/2464 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 14 december 2022 amending regulation (EU) no 537/2014, directive 2004/109/EC, directive 2006/43/EC and directive 2013/34/EU, as regards corporate sustainability reporting.

[3] Xu, T. *et al.* Estimating hourly nitrogen oxide emissions over east asia from geostationary satellite measurements **11**.