Satellite-based Quantification of NO_2 Emissions from Global Natural Gas Flaring with a Focus on Asia

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INTRODUCTION

This study aims to assess nitrogen dioxide (NO_2) emissions accompanying methane (CH_4) emissions associated with natural gas flaring using satellite remote sensing data. We employ an improved divergence flux method with TROPOspheric Monitoring Instrument (TROPOMI) data to estimate NO_2 emissions from global gas flaring hotspots detected by Visible Infrared Imaging Radiometer Suit (VIIRS). This method considers wind pattern changes, incorporates corrections for topography and chemical loss of NOx, yielding precise estimates. Results show significant NO_2 emissions from oil and gas facilities and gas flaring areas. The research contributes to evaluating global NO_2 emissions and enhancing fossil fuel exploitation inventories.

DATASETS (Period 2022)

- TROPOMI Level 2 NO_2 Column Density
- VIIRS Natural Gas Flaring
- ECMWF – ERA5 Meteorological Data
- ESCiMo – Ozone Climatology

METHODOLOGY

Flux Divergence Method

Emission = Divergence + Sink

$$E_{NOx} = f_{NOx}\left(\nabla(V.u) + \frac{V}{\tau}\right)$$

Scale Factor (f_{NOx})

$$\frac{[NO_x]}{[NO_2]} = 1 + \frac{[NO]}{[NO_2]} = 1 + \frac{J}{k[O_3]}$$

$J = 0.0167 \times \exp(-0.575 / SZA)\ s^{-1}$

$k = 2.07 \times 10^{-12} \times \exp(-1400/T)$

O_3 climatology from ESCiMO

Divergence

$$D = \nabla(wV) = w.\nabla V + V.\nabla w$$

$$A = w.\nabla V$$

Topography Correction

$$C_{topo} = V/H_{sh}\ .w_0\ .\nabla z_0$$

H_{sh} - NOx scale height

w_0 - surface wind speed

z_0 - surface elevation

$$A^* = A + f\ .C_{topo}$$

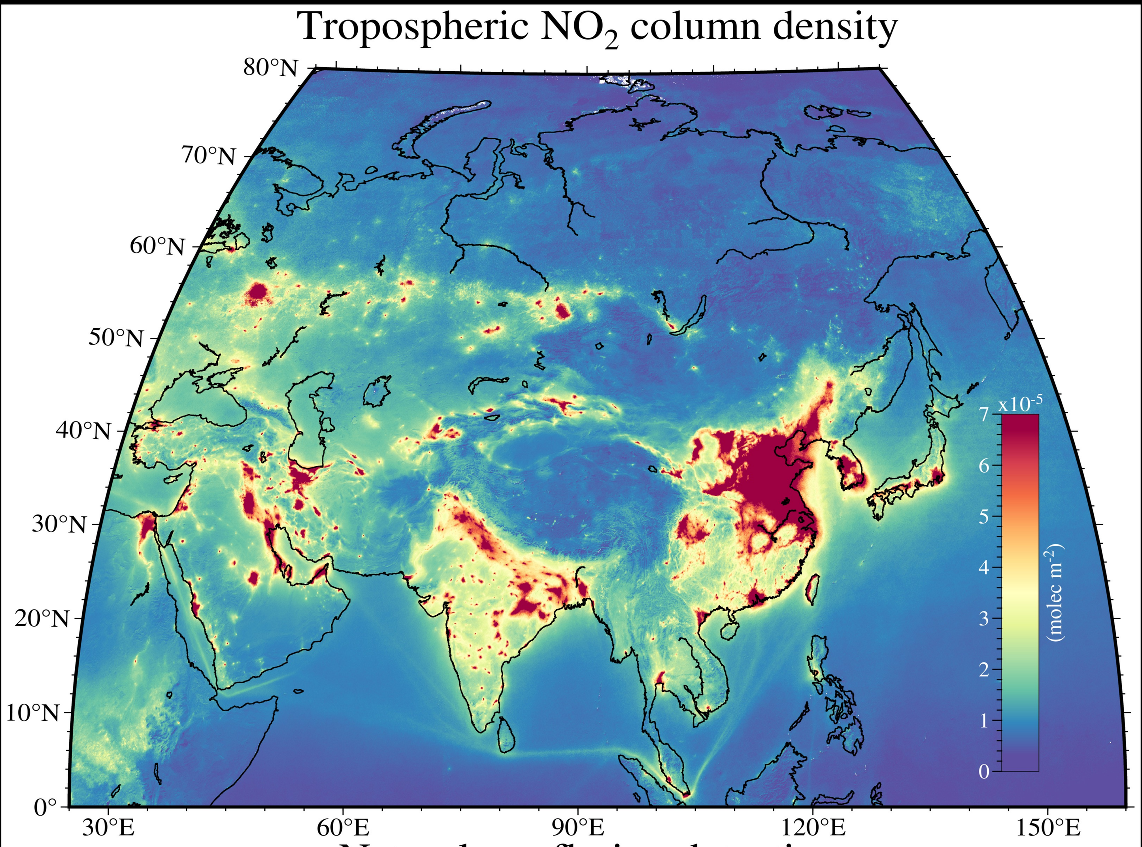
Sink

$$\tau = 1/(k_{OH+NO2}\ .[OH])$$

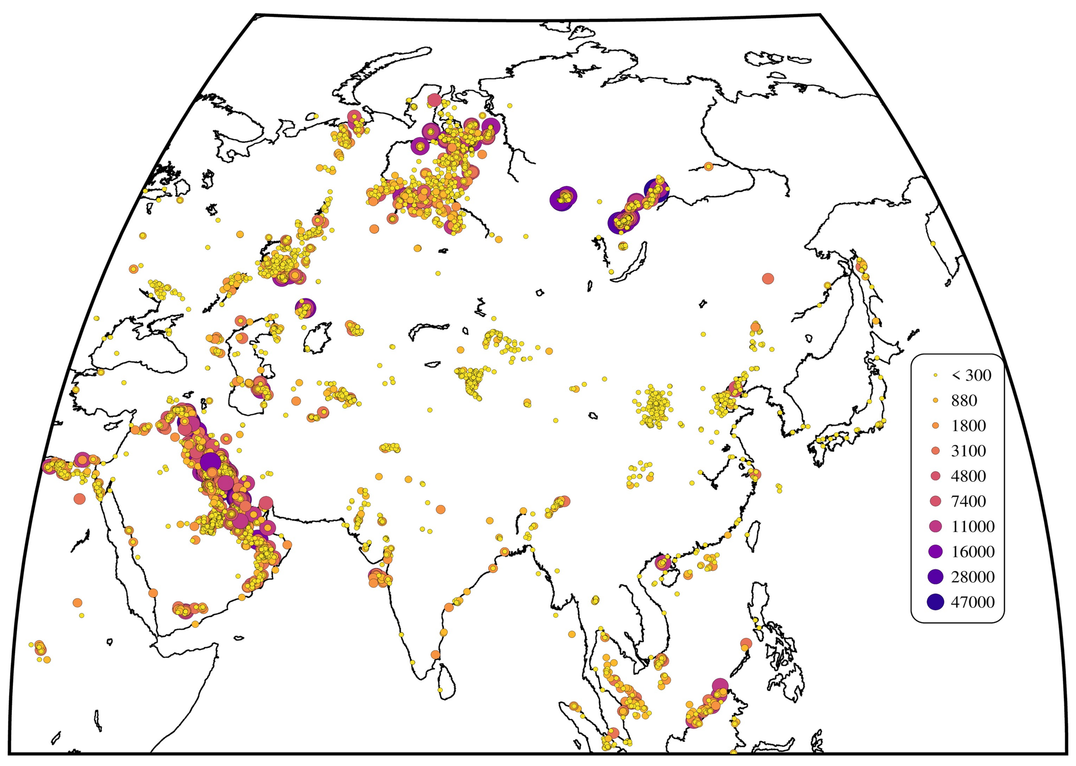
OH is calculated empirically between the photolysis frequency of Ozone and OH.

$OH = 3.38 \times 10^6\ .\ (J(O(^1D)).10^5)^{0.956} + 0.162 \times 10^6$

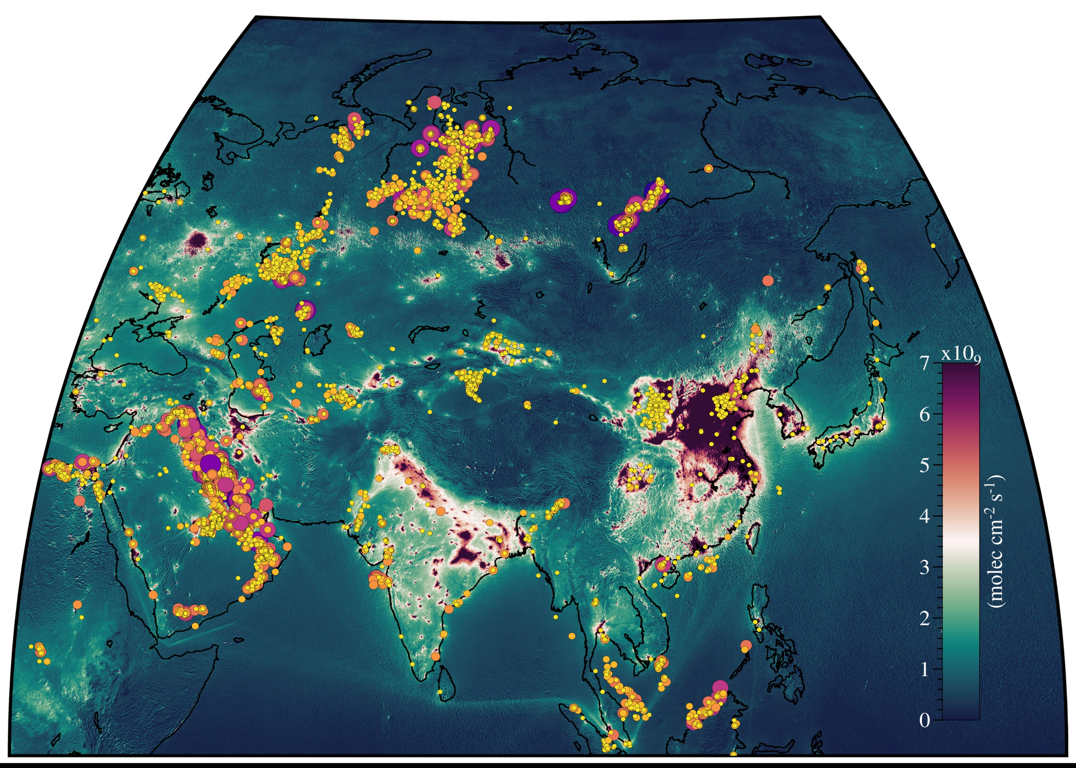
Tropospheric NO_2 column density

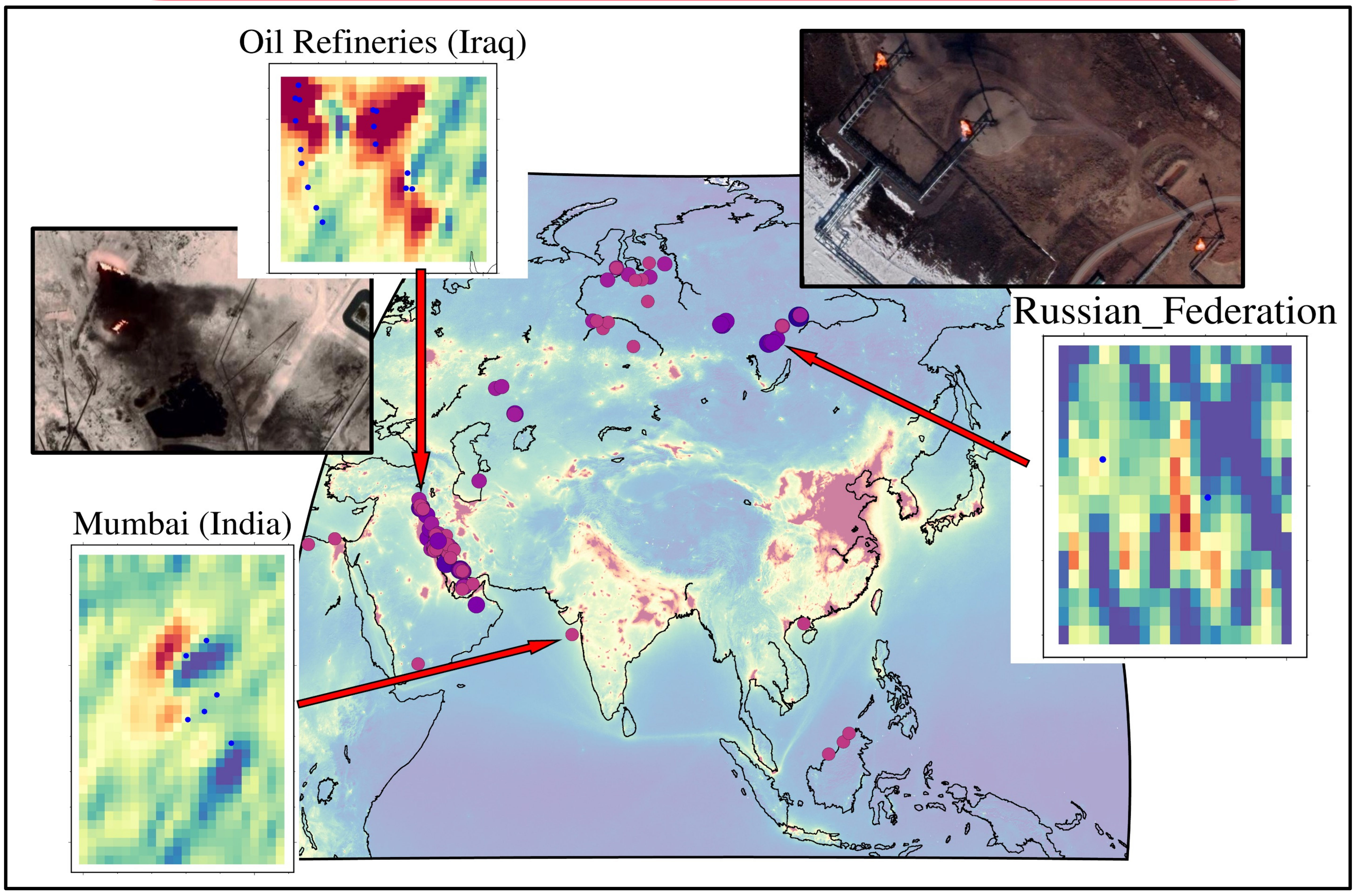


Natural gas flaring detections



NO_2 Emission





The provided data presents estimated NOx emissions based on observations.

Country (sites)	E_{NO2} (t day^{-1})
India (Mumbai)	49.9
Malaysia	38.9
China	67.9
Turkmenistan	77.4
Iraq_1	187.8
Iraq_2	142.2
Iraq_3	95.7
Kuwait_1	176.3
Kuwait_2	101.9
Qatar	183.5

Country (sites)	E_{NO2} (t day^{-1})
Saudi_Arabia_1	120.1
Saudi_Arabia_2	167.9
Russian_Federation_1	30.5
Russian_Federation_2	80.1
Russian_Federation_3	76.9
Russian_Federation_4	33.5
Russian_Federation_5	77.9
Russian_Federation_6	41.2
Russian_Federation_7	70.9
Russian_Federation_8	38.6

SUMMARY

These NOx emission maps offer detailed spatial information, surpassing the accuracy of total NOx quantification. The divergence method is valuable for timely emissions data, evaluating inventories, monitoring trends, and providing detailed NOx distribution. This analysis can be extended globally for areas lacking emission data.