Variability of Nitrogen Dioxide from Space over India during Last Two Decades (2005-2019)

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Abstract

• Nitrogen dioxide (NO$_2$) is a criteria pollutant that is combustion derived and a strong marker of traffic, power plants, etc., associated with adverse health effects. In India, ground-based measurements of NO$_2$ are quite limited, thereby hindering a comprehensive exposure assessment. This work aims to address these two critical gaps by first providing a long-term spatial heterogeneity of NO$_2$ and linking it to major contributing sources over the Indian region, and secondly, by examining the variability in view of the land use pattern and its changes over the last two decades.

• We analyzed NO$_2$ columnar density from Ozone Monitoring Instrument (OMI) onboard the Aura satellite at a resolution of 0.1° × 0.1° for the period 2005-2019. We also analyzed Global Human Settlement Layer (GHSL) data to identify the land use as high-density urban (HDU), low-density urban (LDU), rural (RU), and no settlement (NS).

• The spatial analysis found high NO$_2$ concentrations (>5×10$^5$ Molecules/cm$^2$) in eastern (coal belt with many power plants) and northern India, along with a few locations in central India. The analysis revealed that per year change in NO$_2$ over two decades showed an increasing trend (>2×10$^3$ Molecules/cm$^2$ at 95% CI) in almost every part of India while interestingly, very few places showed a strong decreasing trend also. The analysis also revealed that NO$_2$ concentrations increased by 25.9%, 29.6%, 12.5%, and 23.07% from 1.35×10$^{15}$, 1.35×10$^{15}$, 1.6×10$^{15}$, 1.95×10$^{15}$ molecules/cm$^2$ in 2005 to 1.7×10$^{15}$, 1.75×10$^{15}$, 1.8×10$^{15}$, 2.4×10$^{15}$ molecules/cm$^2$ in 2019 respectively in ‘NS,’ ‘RU,’ ‘LDU,’ and ‘HDU’ classes of the Indian landmass. NO$_2$ concentrations significantly increased over India in the past two decades.
Methods

1. Satellite NO₂ Long Term (2005-2019) Spatial Heterogeneity Analysis over India
   - OMI NO₂ averaged over two decades annually & seasonally for **climatology** plot
   - Annualised rate of change (**trends**) of annual NO₂ conc. calculated.

2. Analysis of change of NO₂ in different Settlement Classes
   - GHSL data (1Km) has re-gridded to match NO₂ (10 Km) resolution (using Nearest Resampling Technique)
   - We overlayed both datasets to find changes in NO₂ in different settlement classes, and change in NO₂ with changing settlement classes
Figure 1. Satellite NO$_2$ Annual Climatology (2005-2019) over India
Figure 2. The Seasonal Tropospheric NO$_2$ Anomaly over India (2005-2019)
Figure 3. Spatial patterns of Annualized Rate of Change of Annual NO$_2$

OMI NO$_2$ Annual Trends (2005–2019)
Figure 4. NO$_2$ and Settlement Classes

$M^*$ represents the median value of change in NO$_2$ from 2005 to 2015.

ANC$^*$ represents total anthropogenic contribution.
Conclusion

1. Eastern coal belt and northern region (dominated by major sources), parts of Maharashtra and Telangana are the major hotspots of NO₂ emissions with concentrations >3.5×10¹⁵ Molecules/cm².

2. The highest NOₓ emitting sector is the power sector, followed by transportation, industrial, agricultural and residential.

3. Compared to other seasons, the southern part of India has slightly higher NO₂ concentrations in the pre-monsoon season, ranging between 0.04×10¹⁵ to 2.5×10¹⁵ Molecules/cm².

4. NO₂ maxima are found in winter seasons while minima in monsoon season

5. Tropospheric NO₂ concentrations show an increasing trend >0.1×10¹⁴ molecules/cm² in almost every part of India except a few showing decreasing trends though insignificant trends.

6. 12-30% shift in urban-rural NO₂ columnar concentrations observed in the last decade.

7. 11-40% OMI NO₂ columnar concentrations are attributable to anthropogenic contributions in different classes; the rest are the background concentrations.
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• All analysis is done using MATLAB R2019b (Source: IIT Delhi) and ArcGIS Pro 2.6 (Source: University of Queensland)

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