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

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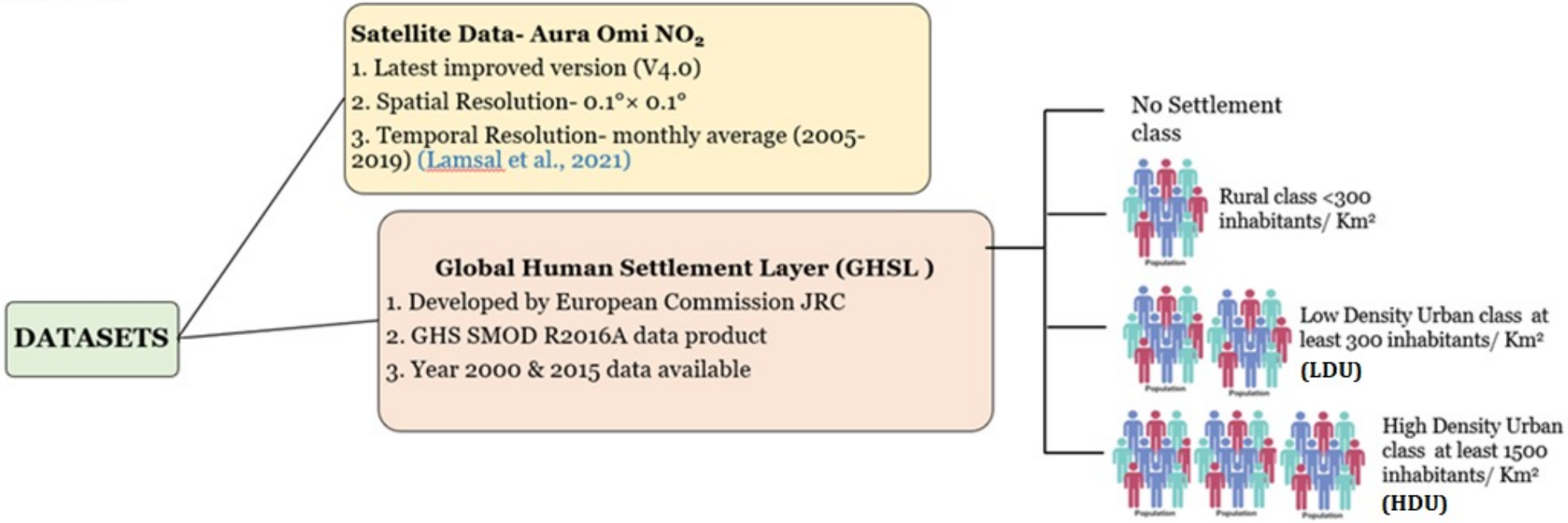
Abstract

- 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 $0.1° \times 0.1°$ 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 ($>5\times10^5$ 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 ($>2\times10^3$ 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 NO_2 Long Term(2005- 2019) Spatial Heterogeneity Analysis over India

- OMI NO_2 averaged over two decades annually & seasonally for **climatology** plot
- Annualised rate of change (**trends)** of annual NO_2 conc. calculated.

2. Analysis of change of NO_2 in different Settlement Classes

- GHSL data (1Km) has re-gridded to match NO_2 (10 Km) resolution (using Nearest Resampling Technique)
- We overlayed both datasets to find changes in NO_2 in different settlement classes, and change in NO_2 with changing settlement classes

Figure 1. Satellite NO_2 Annual Climatology (2005-2019) over India

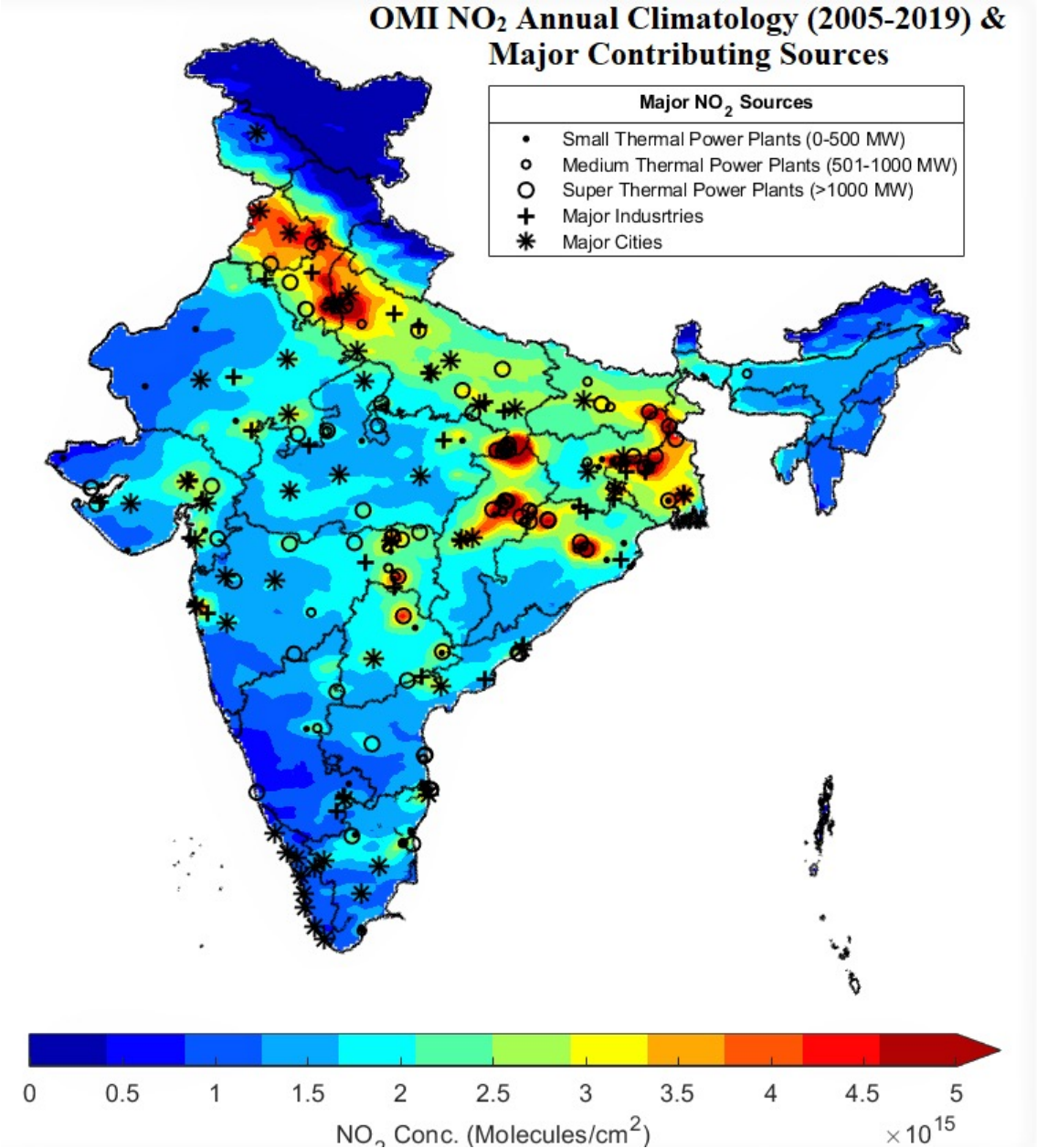


Figure 2. The Seasonal Tropospheric NO_2 Anomaly over India (2005-2019)

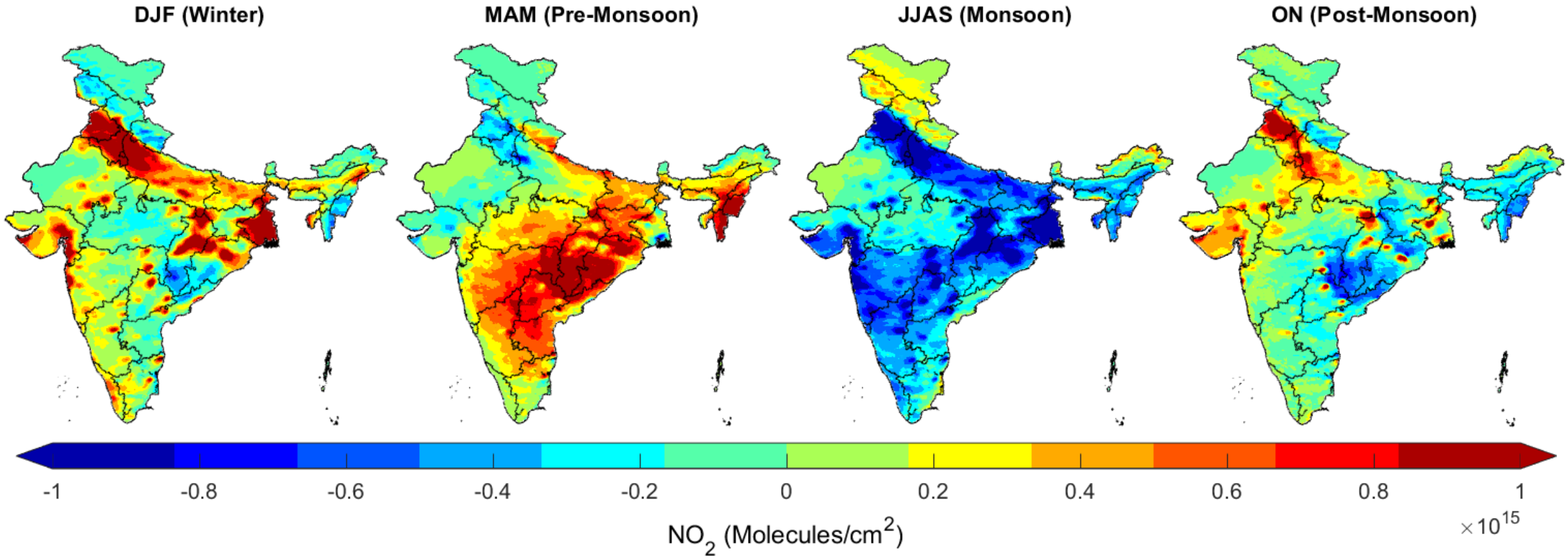


Figure 3. Spatial patterns of Annualized Rate of Change of Annual NO_2

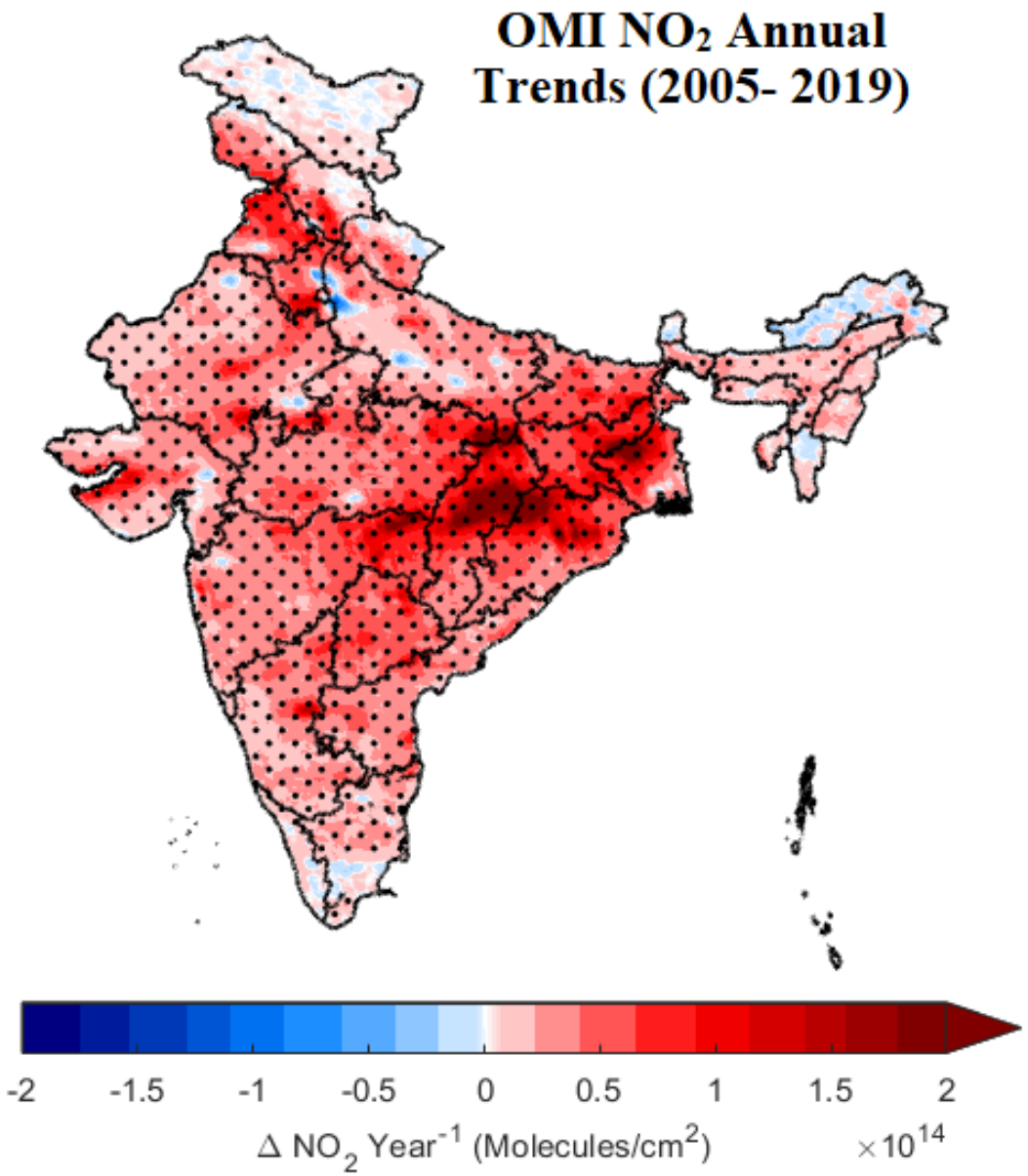
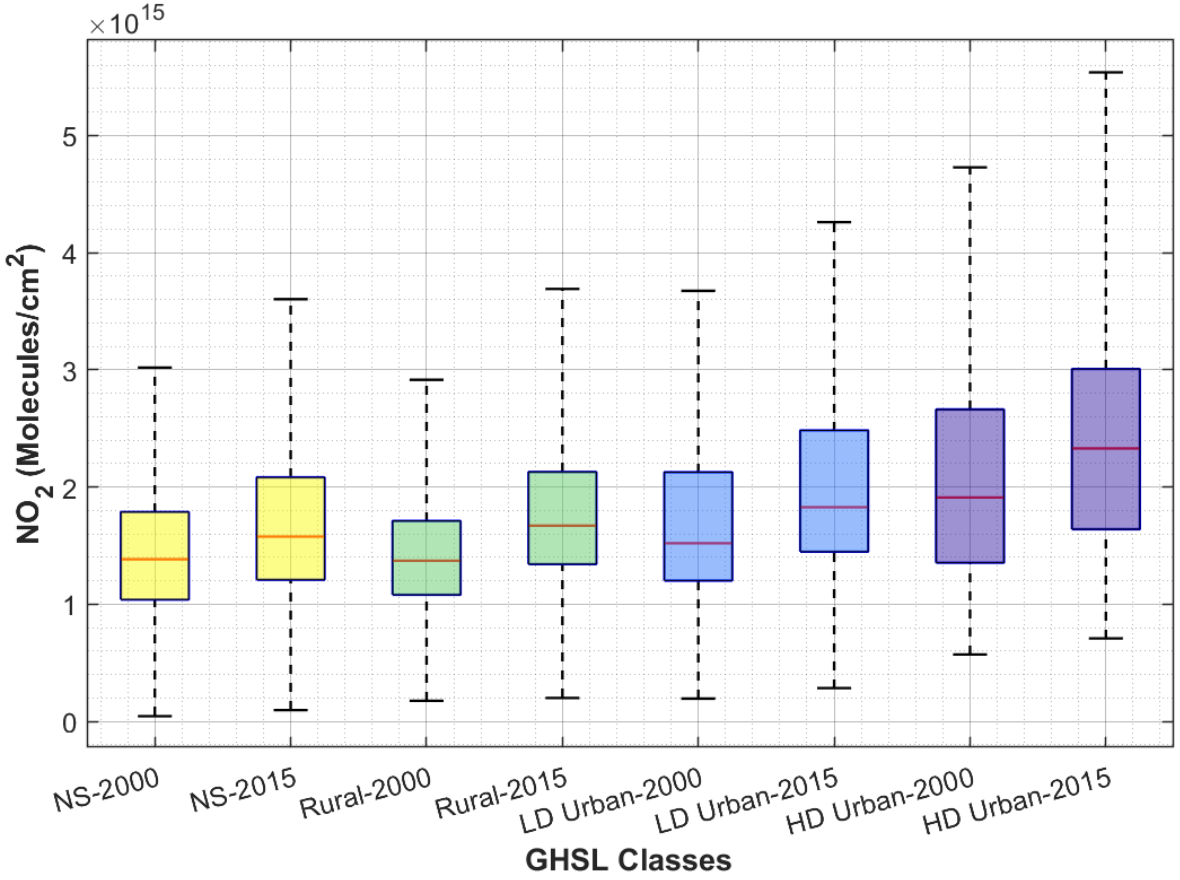


Figure 4. NO_2 and Settlement Classes



Settlement Data Classes 2015

Settlement Data Classes 2000	No Settlement Grids	Rural Grids	Low density Urban Grids	High Density Urban Grids	
0	0 – 0 NS – NS 91.5% Grids **M*= 2.2e+14**	0 – 1 NS – Rural 7.1% Grids **M*= 2.9e+14** **ANC*= 24.5%**	0 – 2 NS – LDU 1.1% Grids **M*= 2.5e+14** **ANC*= 11.6%**	0 – 3 NS – HDU 0.3% Grids **M*= 2.7e+15** **ANC*= 19%**	**No Settlement Grids**
1	1 – 0 Rural – NS 10.2% Grids M*= 2.5e+14	1 – 1 Rural – Rural 76.1% Grids **M*= 2.6e+14** **ANC*= 14.6%**	1 – 2 Rural - LDU 12.1% Grids **M*= 2.9e+14** **ANC*= 24.7%**	1 – 3 Rural – HDU 1.6% Grids **M*= 3.7e+14** **ANC*= 40.8%**	**Rural Grids**
2	2 – 0 LDU – NS 4% Grids M*= 2.4e+14	2 – 1 LDU – Rural 10% Grids M*= 2e+14	2 – 2 LDU – LDU 70.9% Grids **M*= 2.8e+14** **ANC*= 20.4%**	2 – 3 LDU – HDU 15.1% Grids **M*= 2.8e+14** **ANC*= 21.3%**	**Low Density Urban Grids**
3	3 – 0 HDU – NS 0.6% Grids M*= 1e+14	3 – 1 HDU – Rural 0.2% Grids M*= 1.28e+14	3 – 2 LDU – HDU 4.6% Grids M*= 3.4e+14	3 – 3 HDU – HDU 94.6% Grids **M*= 3.3e+14** **ANC*= 32.4%**	**High Density Urban Grids**
	0	**1**	**2**	**3**	

Settlement Data Classes 2015

Settlement Data Classes 2000

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 NO_2 emissions with concentrations $>3.5\times10^{15}$ Molecules/cm^2.
2. The highest NO_x 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 NO_2 concentrations in the pre-monsoon season, ranging between 0.04×10^{15} to 2.5×10^{15} Molecules/cm^2.
4. NO_2 maxima are found in winter seasons while minima in monsoon season
5. Tropospheric NO2 concentrations show an increasing trend $>0.1\times10^{14}$ molecules/cm^2 in almost every part of India except a few showing decreasing trends though insignificant trends.
6. 12-30% shift in urban-rural NO_2 columnar concentrations observed in the last decade.
7. 11-40% OMI NO_2 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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