Monitoring long –term changes in NO_2 pollution from global to city scale: A journey guided by environmental laws and policies

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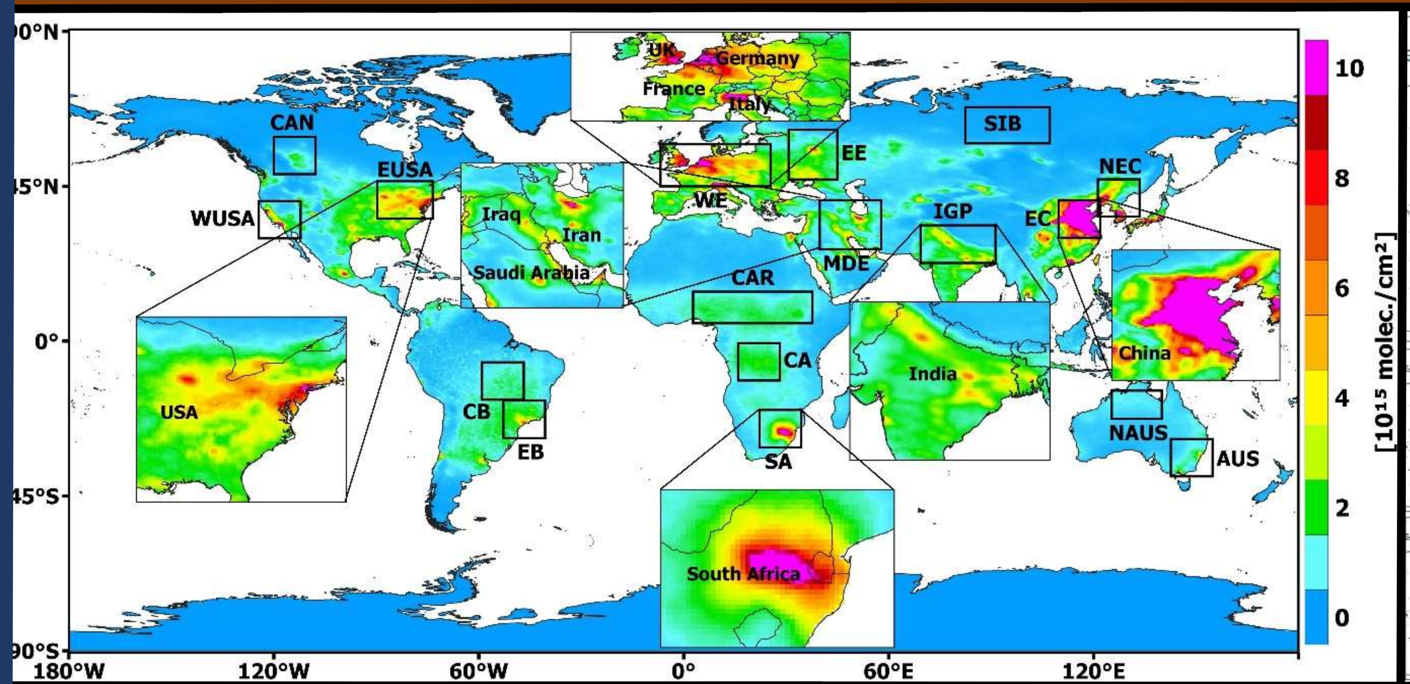
ABSTRACT

Air pollution presents a formidable global challenge, exerting profound impacts on climate, human well-being and the world economy. Notably, atmospheric NO_2, predominantly of anthropogenic origin, arises from diverse sources, including vehicular and industrial emissions. This study investigates the changes in global atmospheric NO_2 through analysis of satellite and ground-based data, focusing on the period from 2002 to 2019. Elevated NO_2 levels (> 8 × 10^{15} molec./cm^2) are identified in the USA, Europe, India, China, the Middle East (MDE), South Africa (SA), Central Africa (CA) and selected regions in Brazil. Seasonal variability is evident, with peak concentrations in winter, largely influenced by meteorological conditions and biomass burning. While NO_x emissions from road transport dominate the USA and Europe, various industrial activities drive elevated NO_2 levels in East China (EC), the Indo-Gangetic Plain (IGP) and SA. Noteworthy is the substantial decline (approximately -0.1 × 10^{15} molec./cm^2/year) in NO_2 observed in the USA and Europe during the study period. In contrast, significant positive trends (approximately 0.06–0.1 × 10^{15} molec./cm^{2}2/year) are noted in MDE, EC, SA, CA and IGP. An additional analysis of NO_2 pollution in 3000 global cities reveals a declining trend in most cities in the USA and Western Europe (WE) at -0.1 × 10^{15} molec./cm^2/year. Conversely, cities in India, China, Africa, Southeast Asia, MDE, and South America exhibit positive trends in NO_2, ranging from 0.04 to 0.1 × 10^{15} molec./cm^2/year. The decreasing NO_2 trends in the developed countries of North America and Europe are attributed to the enforcement of strict vehicular norms, resulting in a significant reduction in road transport emissions. This study offers a comprehensive view of recent NO_2 pollution trends across countries and cities, highlighting the contrasting trajectories between developed and developing regions. It also suggests the potential strategies for developing nations to mitigate air pollution.

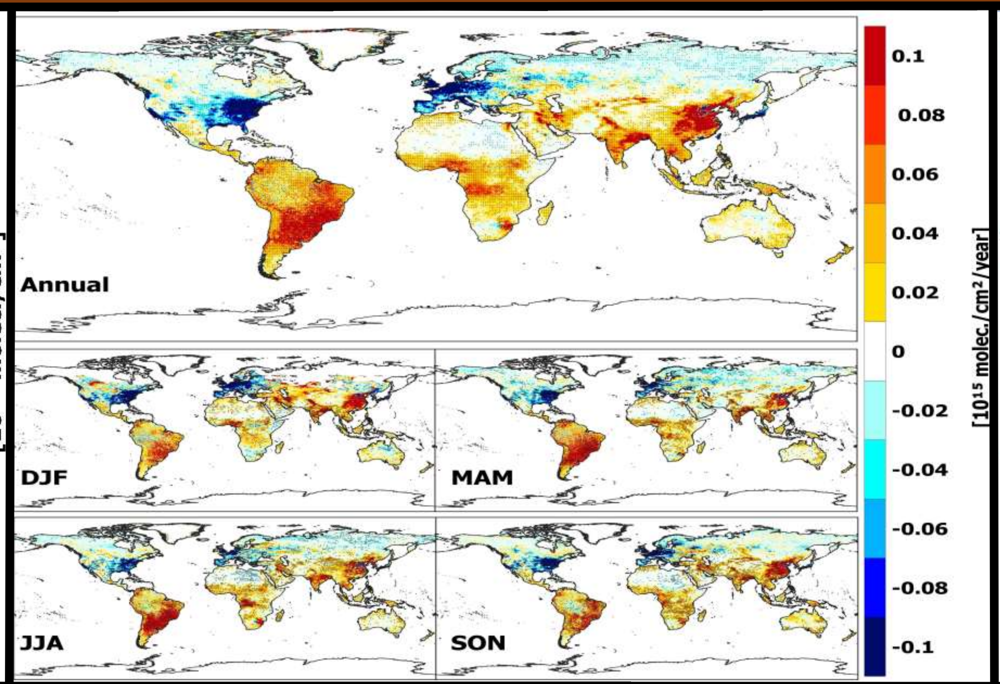
DATA AND METHODOLOGY

- NO_2 merged data from the satellites GOME 2a & 2b and SCIAMACHY for 2002-2019 period.
- We have used EDGAR Emission inventory data for calculating emission, at a resolution of 0.1° × 0.1°.
- The HYSPLIT model at a 1°×1° grid to calculate 7-day backward trajectories, at 500 meters above ground.
- Information regarding the environmental laws and policies in different countries for the impact assessment.
- To find the annual and seasonal distribution, the composite data are made.
- Emission of NO_2 is calculated using EDGAR inventory.
- Using the linear regression method we have calculated the trend.
- HYSPLIT model were used to analyse the air mass transport.

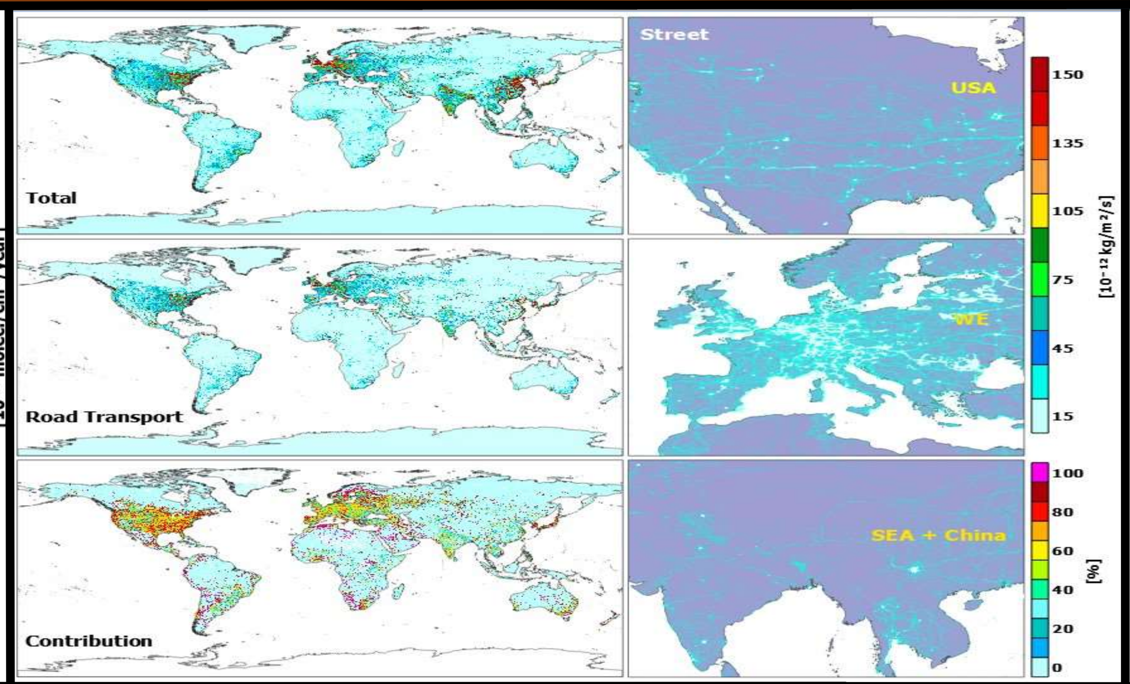
RESULTS AND DISCUSSION



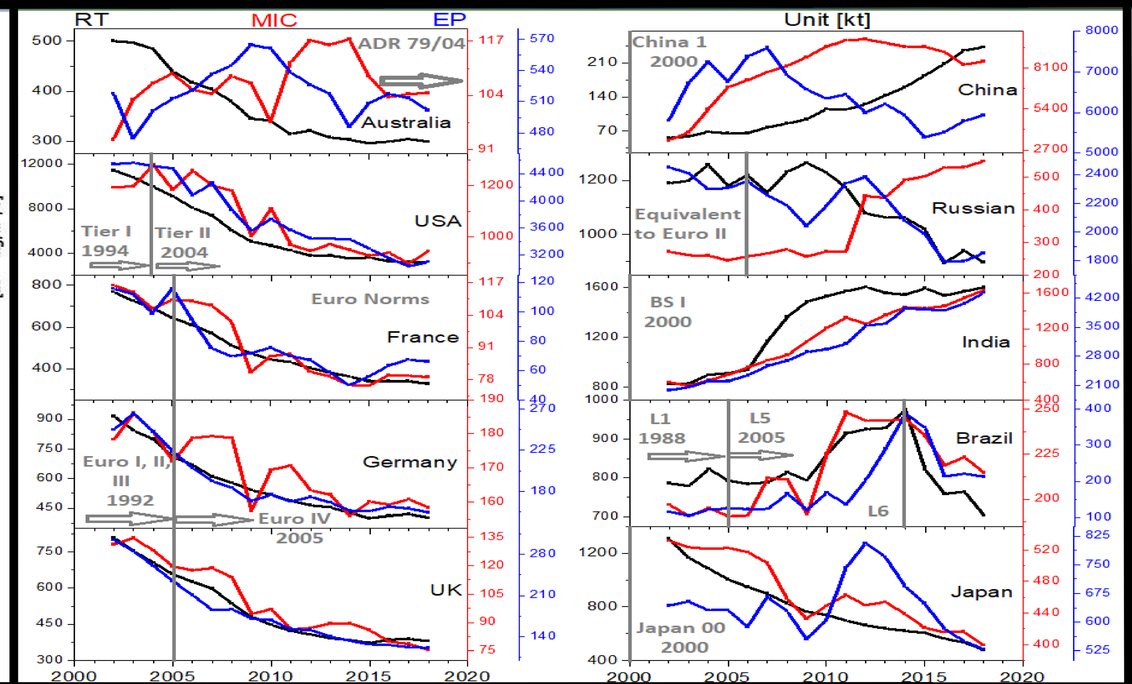
- The annual mean distribution of NO_2 in the northern and southern hemispheres reveals its large spatial heterogeneity.
- We have identified six major global hotspots:
  - Eastern China , Western Europe and Eastern USA (EUSA): 5–10 × 10^{15} molec./cm^2
  - Middle East and Indo Gangetic Plain : 4–18 × 10^{15} molec./cm^2
  - South Africa : 8–10 × 10^{15} molec./cm^2



- Significant negative trends in:
- EUSA and WE (-0.1 × 10^{15} molec./cm^2/year).
- Significant positive trends in:
  - India (0.06–0.1× 10^{15} molec./cm^2/year)
  - EC (0.1 × 10^{15} molec./cm^2/year)
  - MDE (0.04–0.1 × 10^{15} molec./cm^2/year)
  - Brazil (0.06–0.08 × 10^{15} molec./cm^2/year)
  - SA (0.08–0.1 × 10^{15} molec./cm^2/year)



- Vehicular emissions are one of the most dominant sources of NO_2 in the atmosphere.
- Emissions from road transport are more dominant in the USA and Europe, where road densities are very high.
- Road transport has around 60–90% contribution to the total emissions in the USA and WE.
- Emissions of NOx from anthropogenic activities are very high;
- EUSA (105–150 × 10^{-12} kg/m^2/s)
- WE (135–150 × 10^{-12} kg/m^2/s)
- EC (135–150 × 10^{-12} kg/m^2/s)
- Emissions from road transport are more dominant in the USA and Europe, where road densities are very high.



- NOx emissions from road transport are decreasing in the USA and European countries.
- However, emissions from road transport are declining in Japan, Russia and Australia.
- In Brazil all three sources show a decline in NOx emissions since 2014.
- Road transport emissions are increasing in China, which is consistent with the trend of NO_2 there. However since 2007, a decline in NOx emissions from Energy and Power heating (EP) there.
- In India, NOx from road transport exhibits an upward trend until the year 2012, but remain constant thereafter due to Bharat Stage norms.
- NOx emissions from overall anthropogenic activities are decreasing in the USA and Europe, whereas increasing in China and India.

CONCLUSIONS

- This is the first comprehensive analysis of atmospheric NO_2 with respect to environmental polices .
- EC, EUSA, WE, MDE, IGP and SA are the major global hotspots.
- There are seasonal changes, but in some regions like EC, EUSA, WE and SA show seasonal changes very small because of high pollution throughout.
- Seasonal hotspots are mostly in the biomass burning areas, where winter and spring seasons show high values.
- Trajectory analysis show that these regions are affected by local pollution, but CA, CB, EE, NAUS and SIB by long-range transport or biomass burning.
- EC shows highest trends and India, MDE, CA and SA regions how high positive trends, but EUSA and WE show negative trends.
- The global decreasing regions are mostly follow the policies there, e.g. Euro norms and Tier.
- Therefore, this study shows that the stringent polices and laws, and their implementation, can reduce the pollution and thus, reduce the associated adverse health effects and climate change.

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