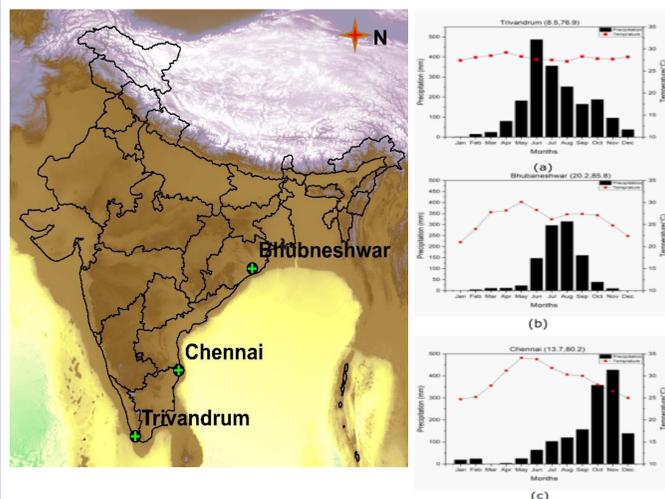


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## Background Motivation

- Trace gases and PMs, along with other pollutants on regional scale have direct adverse effect on human health and agricultural production and due to increase in their concentration they are among the major contributors to global warming
- In view of this Quantifying the source contribution (regional emission due to various anthropogenic activities such as city traffic density vs. long range transport due to meteorological influence) of trace gases and PM over different temporal and spatial scales is of paramount importance.
- We present three-year surface measurements of TGs (O<sub>3</sub>, CO, NO<sub>x</sub>, SO<sub>2</sub> and NH<sub>3</sub>) and PMs (PM<sub>2.5</sub> and PM<sub>10</sub>) at three coastal sites Trivandrum (TVM, 8.5°N, 76.9°E, 5m AMSL), Chennai (CHN, 13.7°N, 80.2°E, 6.7m AMSL) and Bhubaneswar (BHB, 20.2°N, 85.8°E, 45m AMSL) in India.
- Three years' data from the year 2016 to 2018 at TVM and CHN and from the year 2012 to 2014 at BHB were analyzed.
- The principal component analysis (PCA) and concentrated weighted trajectories (CWT) were applied to the dataset to distinguish local and transported pollutants and to identify their potential source region

## Area of Study and Underlying Meteorological conditions



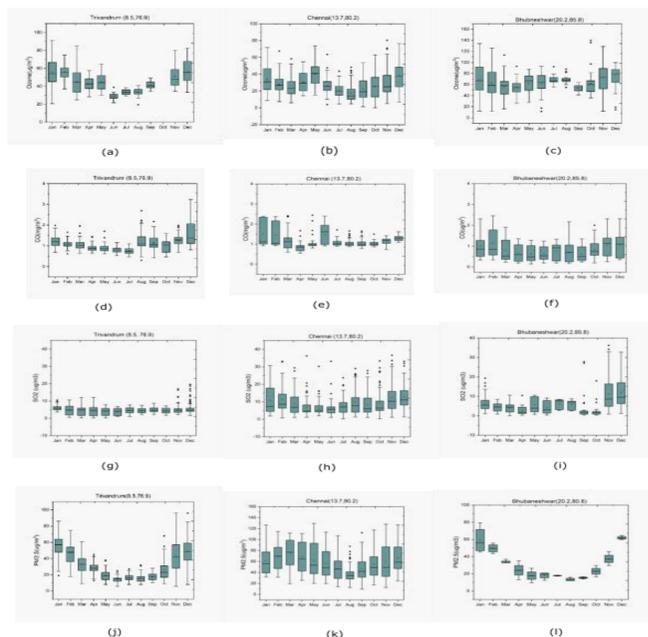
### SITE DESCRIPTION :-

- Measurements of major air pollutants such as O<sub>3</sub>, CO and NO<sub>x</sub>, SO<sub>2</sub> and PM<sub>2.5</sub> along with meteorological parameters were carried out
- At three different urban coastal sites in India, namely located at Trivandrum (8.5N and 76.9E, 70 amsl), Manali (13.1N and 80.2E, 78 amsl) and Bhubaneswar (20.1N and 85.8E ZZ 89 m amsl).
- All the three sites are characterized by flat terrain.
- Although all the three sites are urban types but TVM site is largely devoid of any heavy industrialization, while Chennai and Bhubaneswar sites have heavy industries in their nearby vicinity

### METROLOGICAL CONDITIONS :-

- All three study sites are intercepted by Indian monsoon circulation, particularly TVM and BBR are susceptible to south-west/summer monsoon while CHN is mainly by north-east/winter monsoon
- The mean temperature at Trivandrum varied from 27.4°C to 29.2°C and from 23.4°C - 38°C for Chennai and for Bhubaneswar, it varied from 22.3°C to 30.1°C.
- The highest average monthly precipitation for TVM, CHN and BHB were recorded as 457mm, 314mm and 427mm
- For TVM, BHB in Pre-Monsoon while for CHN in Post-Monsoon season

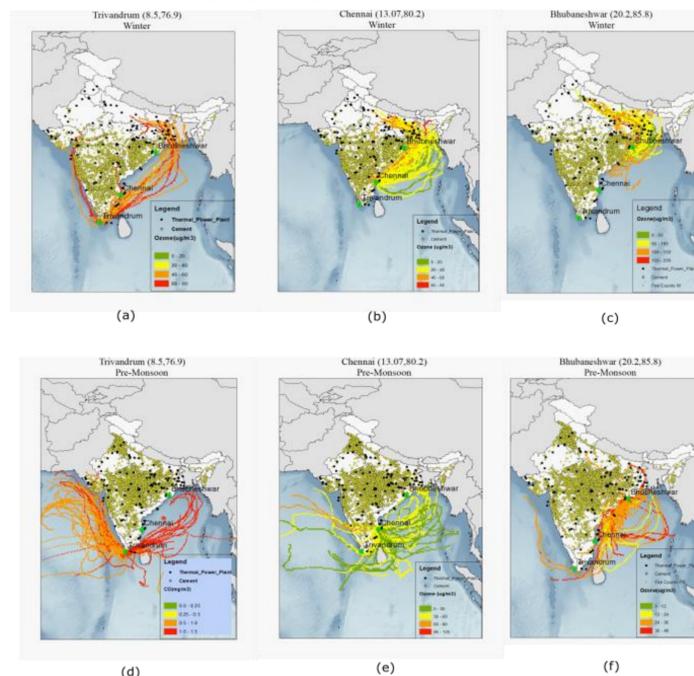
## Annual Variation of surface Pollutants :-



### Annual Variations:-

- Surface O<sub>3</sub>, CO, SO<sub>2</sub> and PM<sub>2.5</sub> variation in average monthly concentration is shown in the fig (a to l) for 2016 to 2018 for TVM and CHN, while for BHB it is from 2012 to 2014
- O<sub>3</sub>, CO, SO<sub>2</sub> and PM<sub>2.5</sub> shows higher monthly average values in Winter seasons for TVM (56.4 ug/m<sup>3</sup>, 1.4mg/m<sup>3</sup>, 5.1ug/m<sup>3</sup> and 52.4 ug/m<sup>3</sup>), CHN (40.4 ug/m<sup>3</sup>, 2.2mg/m<sup>3</sup>, 18.2 ug/m<sup>3</sup> and 78.4ug/m<sup>3</sup>) and BHB (72.6 ug/m<sup>3</sup>, 2.1 mg/m<sup>3</sup>, 19.3 ug/m<sup>3</sup> and 68.6 ug/m<sup>3</sup>)
- While show their lower values during Monsoon seasons for TVM (28.1 ug/m<sup>3</sup>, 0.8 mg/m<sup>3</sup>, 2.8ug/m<sup>3</sup> and 12 ug/m<sup>3</sup>), CHN (19.4 ug/m<sup>3</sup>, 1 mg/m<sup>3</sup>, 3.2 ug/m<sup>3</sup> and 38.4 ug/m<sup>3</sup>) and during Post-Monsoon for BHB (63.4ug/m<sup>3</sup>, 1 mg/m<sup>3</sup>, 2.8 ug/m<sup>3</sup> and 24.7 ug/m<sup>3</sup>)
- An additional peak in the monthly average concentration is observed for O<sub>3</sub>, CO and PM<sub>2.5</sub> for CHN station

## Concentrated Weightage Trajectory Analysis :-



### Concentrated Weighted Trajectory Analysis :-

- Concentrated Weightage Analysis (CWT) is been done for the pollutants measured at all the three sites for all the four seasons individually
- Fig (a to f) shows CWT for Winter and Pre-Monsoon Seasons for all the three station
- In Winter most of the air mass trajectories are passing over heavily industrial region and coming to our measurement sites
- In Pre-Monsoon most of the trajectory are passing over ocean and have marine influence
- In Monsoon there is a clear influence of south west monsoonal winds
- While in Post-Monsoon air mass trajectory are coming from south west and north west direction

## Data Description :-

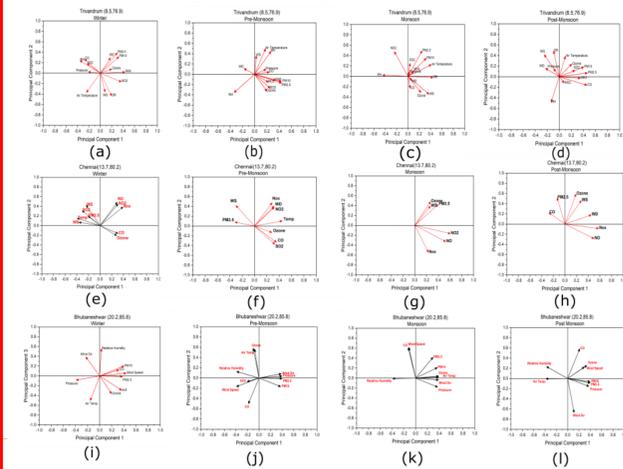
### In-Situ Surface Observation (KSPCB, CPCB and MMT)

Parameters	Temporal Resolution	Vertical Level
Trace gases (O <sub>3</sub> , CO, SO <sub>2</sub> , NO, NO <sub>2</sub> , NH <sub>3</sub> )	Daily and Hourly	Surface
PM <sub>2.5</sub> & PM <sub>10</sub>	Daily and Hourly	Surface
Meteorological Parameters	Daily and Hourly	Surface

### Satellite and Model data :-

- Merra-2 Surface level Trace gases and Particulate matter data is also used
- MODIS Fire Counts Data NASA Giovanni, Source: <https://giovanni.gsfc.nasa.gov/giovanni/>
- Global Data Assimilation System (GDAS) 1 x 1 degree spatial resolution, meteorological data
- Apart from their Thermal Power Plant and Cement Manufacturing Plant data from Industryabout.com, Source: <http://www.industryabout.com/india-industrial-map> were also used in trajectory maps

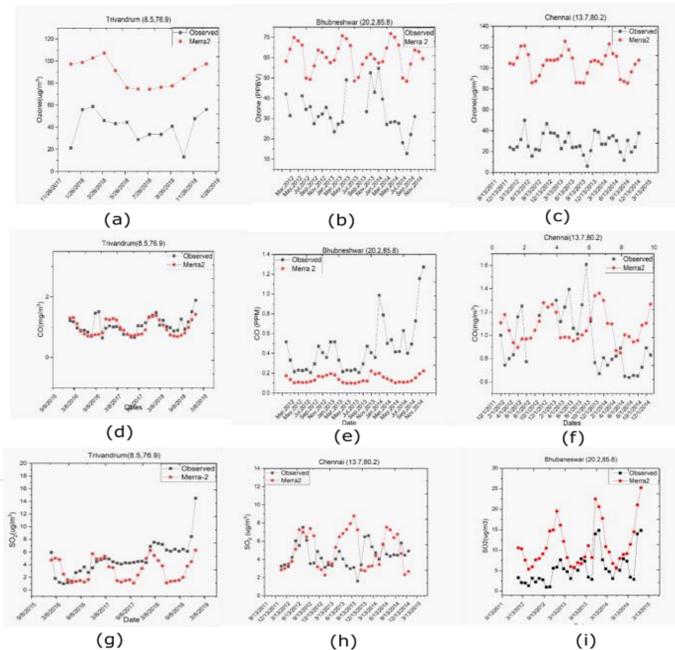
## Principle Component Analysis



### Principle Component Analysis:-

- O<sub>3</sub> and Temperature are negatively correlated with same PCs for all the seasons in TVM
- For CHN, O<sub>3</sub> and Temperature are negatively correlated with same PC for Winter and Post-Monsoon while for Pre-Monsoon they show positive correlation
- For BHB, O<sub>3</sub> show negative correlation with same PC during Winter and Post-Monsoon Season while show positive correlation during Pre-Monsoon and Monsoon season
- Positive Correlation of O<sub>3</sub> and Temperature with PC indicate the local Production of O<sub>3</sub> and negative correlation indicate transported O<sub>3</sub> from far location

## Validation MERRA-2, Surface data with In-Situ Measurements:-



### MERRA-2 Surface Data Validation :-

- Fig (a to i) show comparison of Merra-2 reanalysis surface data with In-situ measured surface pollutants (O<sub>3</sub>, CO and SO<sub>2</sub>)
- For O<sub>3</sub> Merra-2 data shows positive correlations for O<sub>2</sub>, CO and SO<sub>2</sub> but shows more than twice the concentration of what observed through In-situ measurement all the stations
- Also for CO and SO<sub>2</sub>, Merra2 shows positive correlation Overall for all the stations

## Conclusion

- From PCA it was observed that for all the three stations for some seasons O<sub>3</sub>, CO, NO<sub>2</sub> and PM<sub>2.5</sub> are transported from far locations
- With CWT analysis it is observed that the back trajectories pass over Indo-Gangetic and Jharkhand Industrial belt, which could impact the air quality measured at our sites

## Acknowledgement :-

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