

Analysis of Air Pollution levels in India

By Group 21

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Outline



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- **Problem Statement**



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 - **Clustering**
- **Results**



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- ❑ To visualize the states/UTs as hotspots and coldspots on the basis of chi-score and z-score
- ❑ To cluster the states/UTs based on their pollution levels

Data Sets

Data Sets

SO ₂ , NO ₂ and RSPM statistics for all states and cities of India	Link: https://www.kaggle.com/shrutibhargava94/india-air-quality-data Contents: SO ₂ , NO ₂ , RSPM, SPM and PM 2.5 for all the states of India from 1990 to 2015 (csv)
State wise Motor Vehicle statistics	Link: http://mospi.nic.in/sites/default/files/statistical_year_book_india_2015/Table-20.4_0 . Contents: Total registered motor vehicles for each state from 2001 to 2015 (xlsx)
State Wise number of Industries	Links: 2008-2014 data (xlsx)- https://www.mospi.gov.in/sites/default/files/statistical_year_book_india_2015/Table%2014.1_1.xlsx 2001-2006 data (docx)- http://labourbureau.gov.in/ASI_V2_2005_06_TAB27F.docx 2007-08 data (pdf)- http://labourbureaunew.gov.in/UserContent/ASI_Vol_1_2007_08.pdf
Census data of india	Links: 2001 census (html)- https://censusindia.gov.in/Census_Data_2001/Census_data_finder/A_Series/Total_population.htm 2011 census (xls)- http://mospi.nic.in/sites/default/files/statistical_year_book_india_2015/Table%20

Data Sets (contd.)

Geographical coordinates of borders of all States/UTs of India	Link: http://download.oracle.com/otn/samplecode/data-visualization/sample-MapLayers_Maps/INDIA_STATES_051120.zip Contents: A zipped json file containing the coordinates of all state borders of India
All Indian states and their neighbors	Built manually as a csv

Extrapolation of missing data



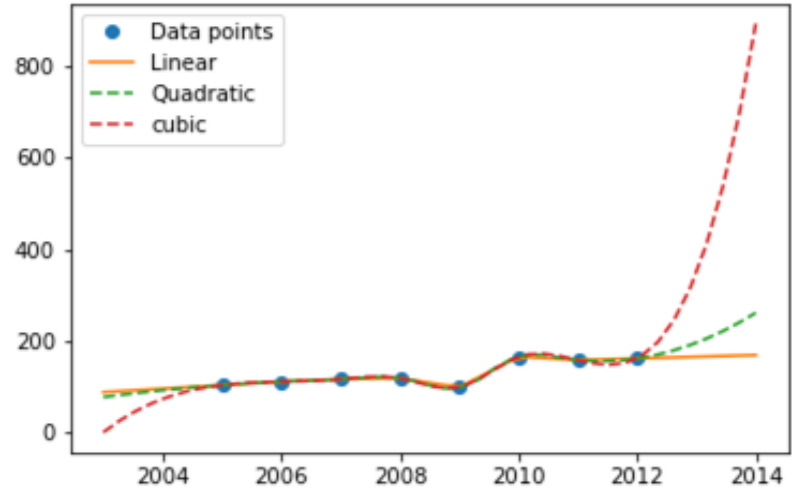
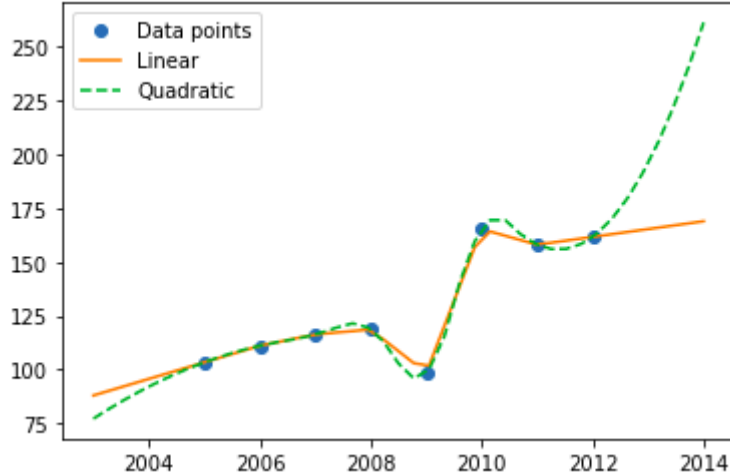


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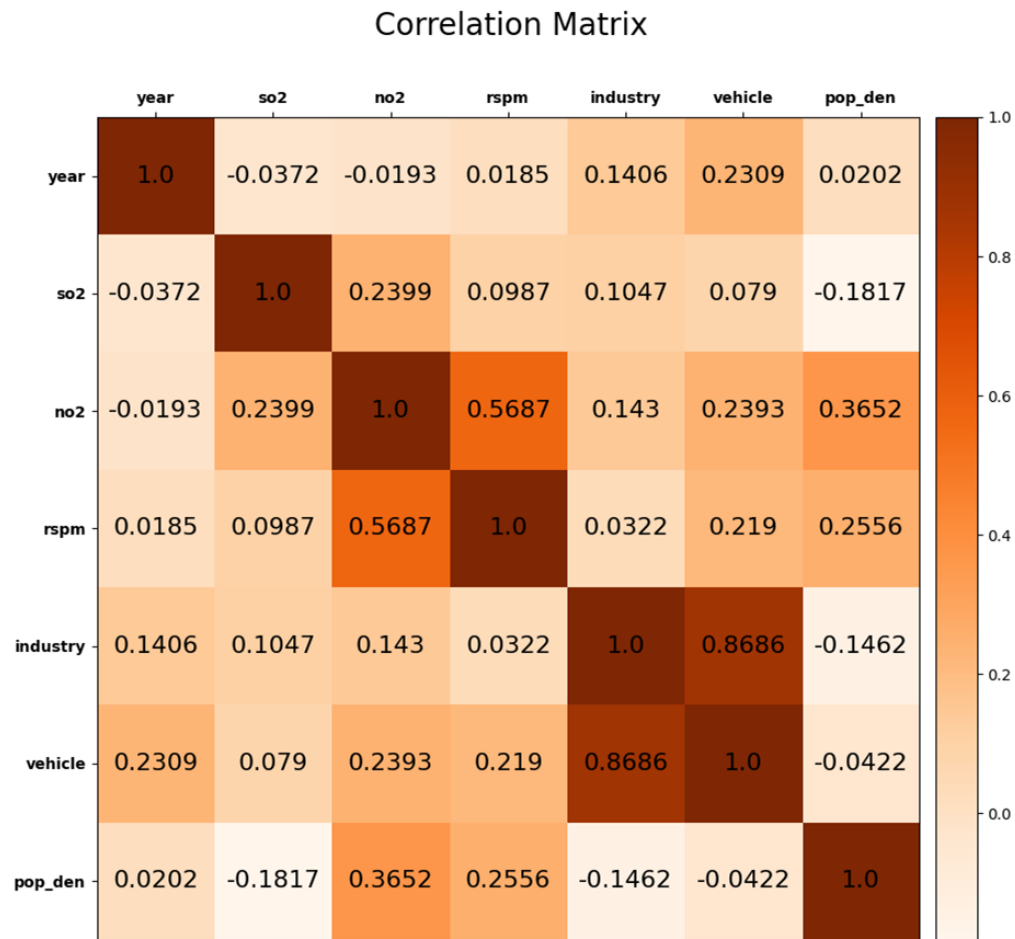


Plots of RSPM values for Bihar



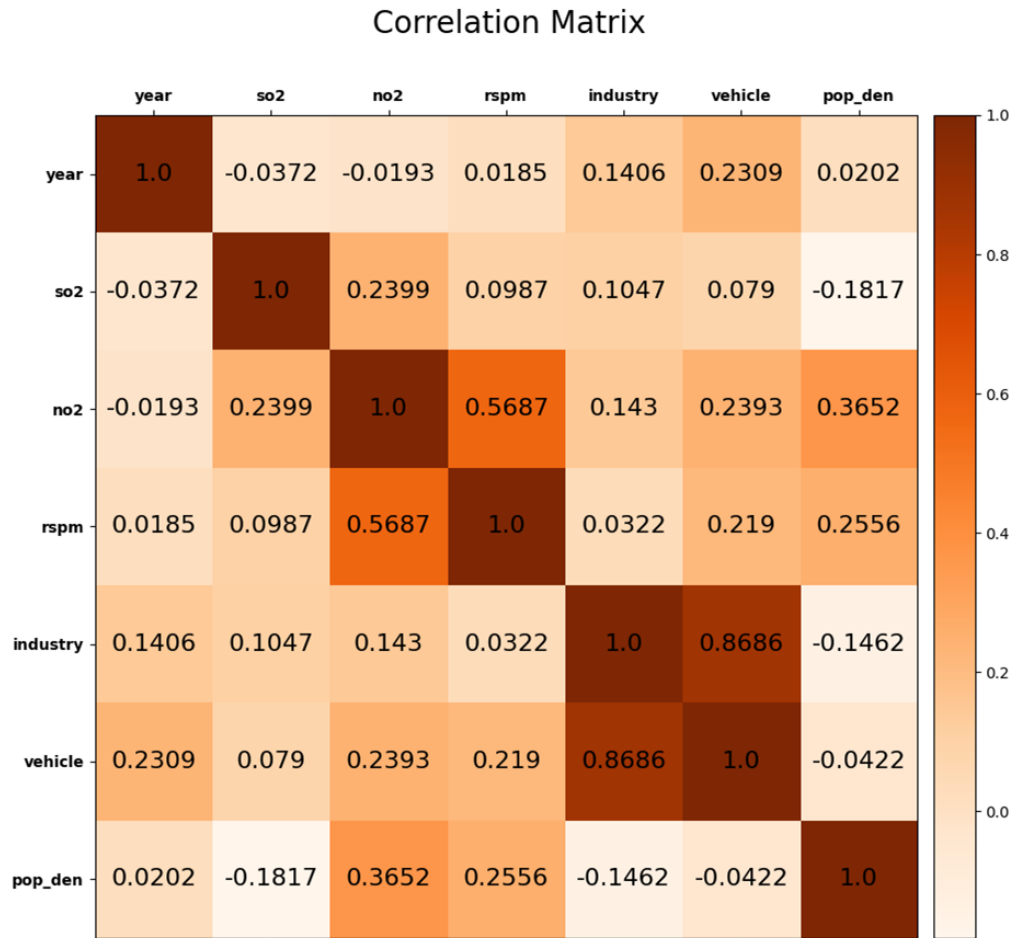
Pearson's Correlation

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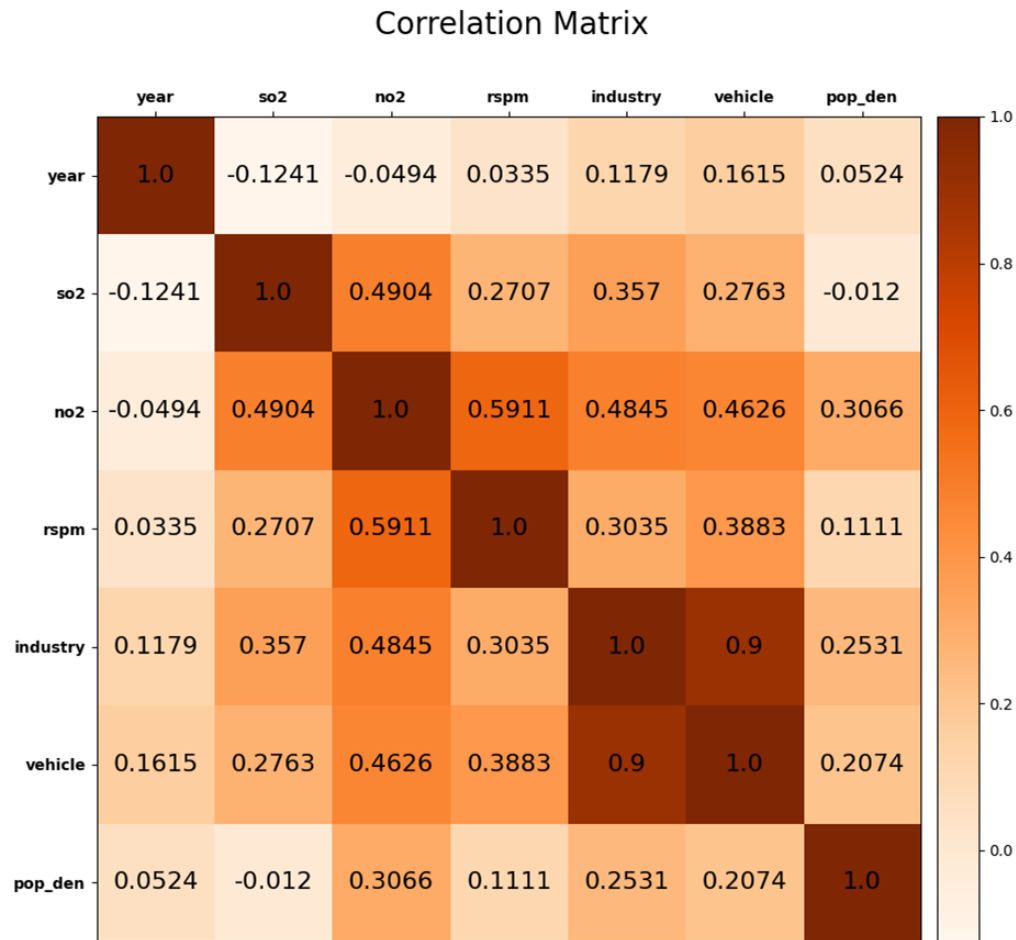
- Only works when features have linear relationship
- Very strong correlation between number of industries and vehicles.
- Correlation of [SO₂, NO₂, RSPM] vs [Industry, Vehicle] surprisingly low.





Spearman's Correlation

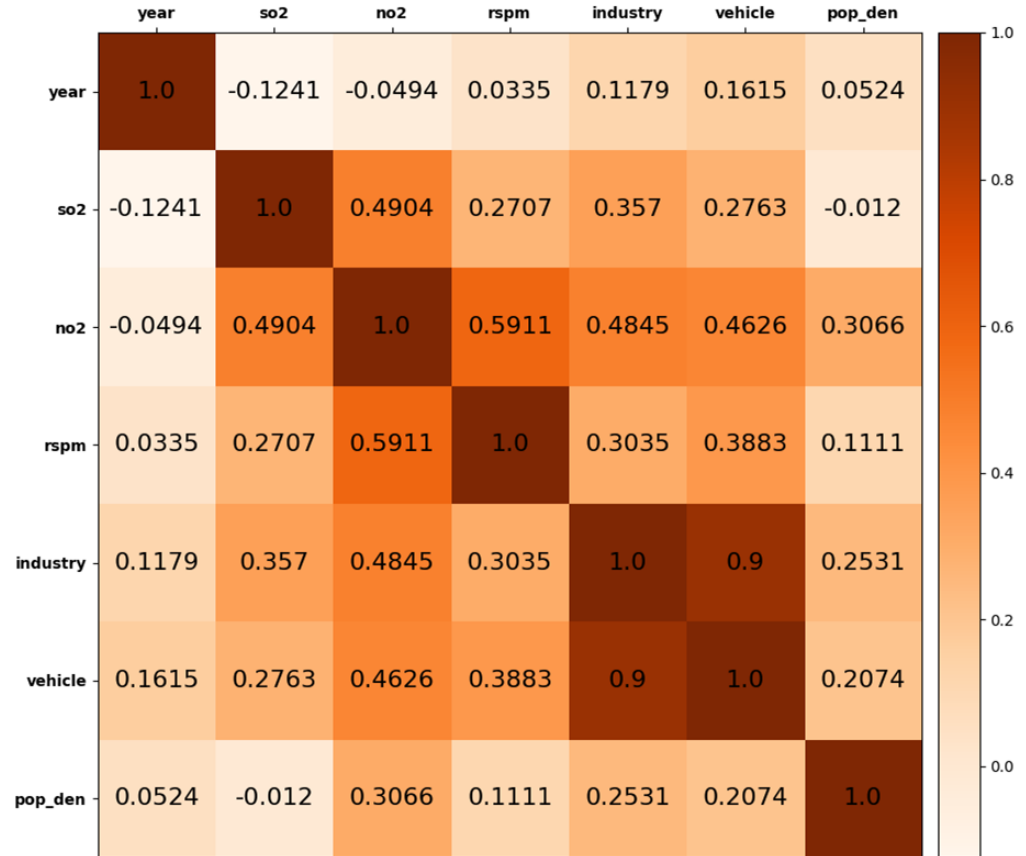
Spearman's Correlation



Spearman's Correlation

- More generic than Pearson.
- Correlation of [SO₂, NO₂, RSPM] vs [Industry, Vehicle] also seems natural.
- Very high correlation(0.9) between no. of vehicles and no. of industries.
- Strong correlation observed between :
 - RSPM and NO₂ levels
 - SO₂ and NO₂ levels
 - NO₂ level and number of vehicles

Correlation Matrix

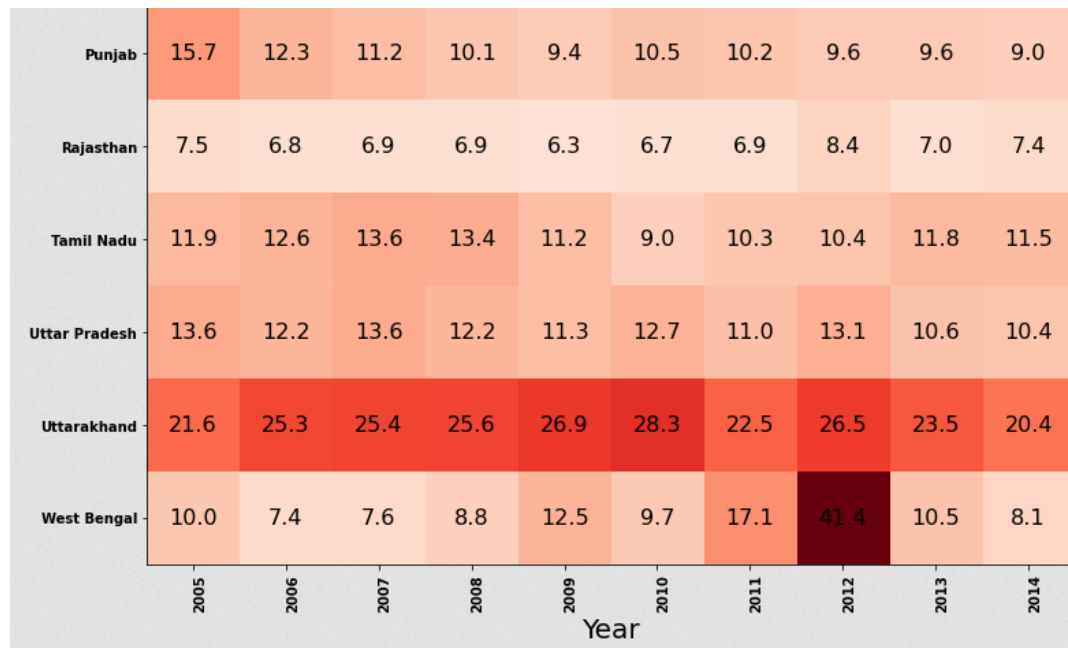




Heatmap of SO₂ concentration for some states

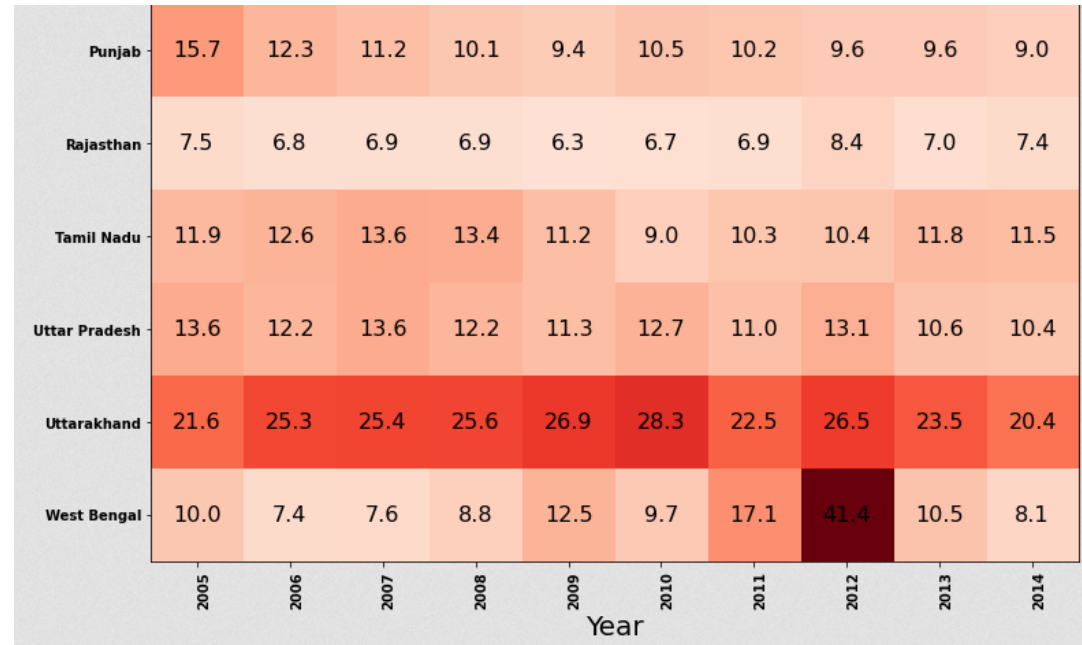


Heatmap of SO₂ concentration for some states



Heatmap of SO₂ concentration for some states

- For most states SO₂ levels haven't showed increasing trend other than Uttarakhand.
- Most prominent reason for SO₂ emission : power generation by burning fossil fuel, followed by vehicular emission.





Heatmap of RSPM concentration for some states



Heatmap of RSPM concentration for some states

Punjab	219.5	215.6	200.6	218.2	203.9	193.6	164.6	161.6	156.3	132.0
Rajasthan	105.1	122.7	115.5	129.4	130.1	164.5	162.9	166.5	172.7	161.6
Tamil Nadu	54.9	58.3	65.0	68.8	71.9	69.9	78.2	72.5	71.6	62.5
Uttar Pradesh	173.4	177.1	169.9	181.7	178.2	183.3	161.2	190.2	184.7	179.3
Uttarakhand	152.9	120.4	100.3	124.6	138.0	151.4	159.8	180.4	141.8	103.3
West Bengal	120.5	112.7	101.4	106.5	151.8	108.8	117.2	106.1	157.5	115.3
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014

Heatmap of RSPM concentration for some states

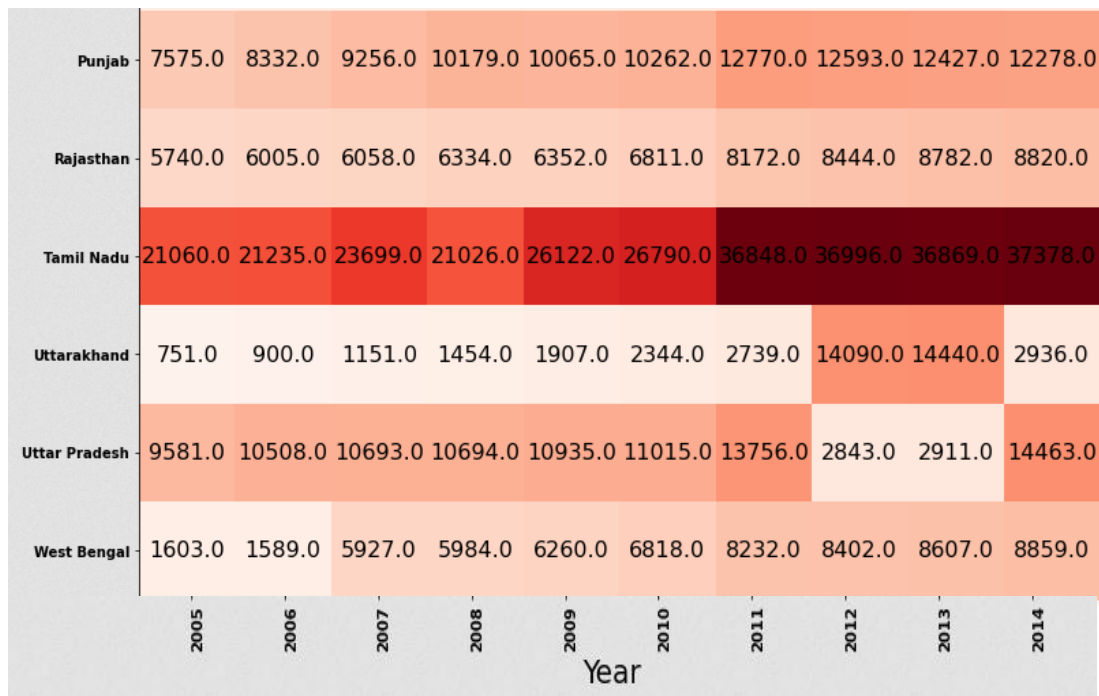
- Punjab's RSPM levels have seen a constant decline. (some state laws?)
- Levels have increased for states like Rajasthan.
- More or less constant throughout period of analysis in UP.

	Year									
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
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Heatmap of industries for some states

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Heatmap of industries for some states

- More and more industries setting up in Tamil nadu. Same for UP, Punjab, WB barring a few years.
- Most of these states affected (in terms of air quality).
- Expected as well by looking at correlation matrix.

	Year									
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Punjab	7575.0	8332.0	9256.0	10179.0	10065.0	10262.0	12770.0	12593.0	12427.0	12278.0
Rajasthan	5740.0	6005.0	6058.0	6334.0	6352.0	6811.0	8172.0	8444.0	8782.0	8820.0
Tamil Nadu	21060.0	21235.0	23699.0	21026.0	26122.0	26790.0	36848.0	36996.0	36869.0	37378.0
Uttarakhand	751.0	900.0	1151.0	1454.0	1907.0	2344.0	2739.0	14090.0	14440.0	2936.0
Uttar Pradesh	9581.0	10508.0	10693.0	10694.0	10935.0	11015.0	13756.0	2843.0	2911.0	14463.0
West Bengal	1603.0	1589.0	5927.0	5984.0	6260.0	6818.0	8232.0	8402.0	8607.0	8859.0



Hotspots using Z-Score



Hotspots using Z-Score

- To find Z-Score, the **Mean Pollutant Concentration (MPC)** for each state is computed, given by:

$$\text{Mean Pollutant Concentration} = \frac{SO_2 \text{ conct.} + NO_2 \text{ conct.} + RSPM \text{ conct.}}{3}$$



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Since it's possible that air pollution of a state is also affected by the increasing air pollution level of its neighboring states, we have defined a state as hotspot or coldspot taking into consideration the pollution level of its neighbors.

- A state is Hotspot if : $MPC_{\text{state}} > \text{Mean}_{\text{neighbor}} + \frac{1}{2} \text{std}_{\text{neighbor}}$
- A state is Coldspot if : $MPC_{\text{state}} < \text{Mean}_{\text{neighbor}} - \frac{1}{2} \text{std}_{\text{neighbor}}$



Choropleth Map to visualize the results of Z-Score

<https://maurya-bitlegacy.github.io/codename-caeli/Maps/zscore-map.html>



Analysis of Results obtained using Z-Score



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- Major Hotspots: Delhi, Maharashtra, Jharkhand, Manipur, Rajasthan



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- **Manipur and Delhi**, both are hotspots, but reasons may vary. Delhi's pollution levels can be attributed to heavy vehicular emissions, dust from construction sites, etc. Manipur's pollution levels are much lower, still hotspot as level of pollutant concentration is more than neighbors.



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- Similarly, problems of **Maharashtra** (a hotspot) possibly revolve around having huge industry-vehicle concentration.
- Major Coldspots: **Kerala, Arunachal Pradesh, Himachal Pradesh, Sikkim, Odisha**. These state not only have low pollutant concentration as compared to their neighbors but in general as well.



Pollutant Concentration Analysis using Chi-Score



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- Used Chi-Squared Test to detect outliers.



Pollutant Concentration Analysis using Chi-Score

- Used Chi-Squared Test to detect outliers.
- Formula used:

$$\chi^2 = \sum_{i=1}^N \frac{(o_i - E_i)^2}{E_i}$$

Where, o : object is to be tested

o_i : value of o in ith dimension

E_i : mean value on ith dimension among all objects

- H_0 : State is not an outlier
 H_1 : State is an outlier
- A state is considered as an **outlier** if it's p-value is less than level of significance (1%).



Choropleth Map to visualize the results of Chi-Squared Test for the year 2014

<https://maurya-bitlegacy.github.io/codename-caeli/Maps/chiscore-map.html>



Limitation of Chi-Squared Test for outlier detection



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- Tells whether a state is an outlier (high or low pollutant concentration) or not but doesn't specify the **nature of outliers**.



Limitation of Chi-Squared Test for outlier detection

- Tells whether a state is an outlier (high or low pollutant concentration) or not but doesn't specify the **nature of outliers**.
- Therefore, we categorised the states as more polluted or less polluted based on Mean Pollutant Concentration levels.



Pollution levels in 2014 and top 5 most polluted cities for every state



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- **Severely Polluted** : $\text{MPC} \geq 65$
- **Moderately Polluted** : $45 \leq \text{MPC} < 65$
- **Less Polluted**: $\text{MPC} < 45$



Pollution levels in 2014 and top 5 most polluted cities for every state

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Choropleth Map for Visualization:

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Clustering



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- To group similar states based on concentrations of SO_2 , NO_2 and RSPM

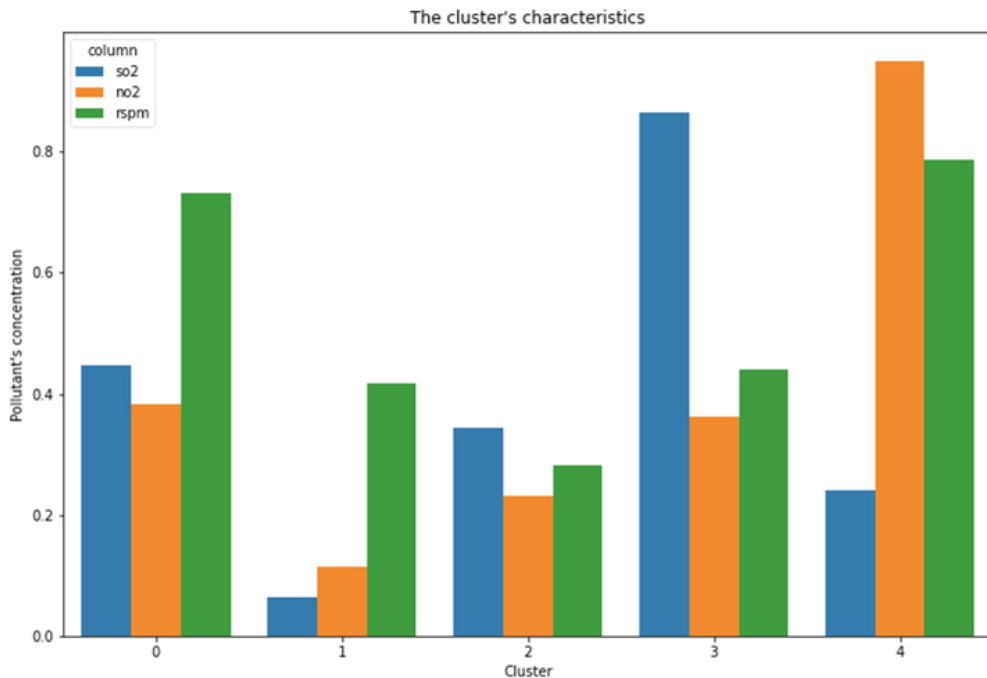


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Interpretation of results obtained from Clustering

Cluster 0: Bihar, Chhattisgarh, Haryana, Jharkhand, Madhya Pradesh, Punjab, Rajasthan, Uttar Pradesh

- High pollution level in Central part of India, especially RSPM.

Cluster 1: Arunachal Pradesh, Chandigarh, Goa, Himachal Pradesh, Jammu & Kashmir, Kerala, Manipur, Meghalaya, Mizoram, Nagaland, Odisha

- Low SO_2 and NO_2 levels and moderate level of RSPM in the hilly regions of India.

Cluster 2: Andhra Pradesh, Assam, Dadra & Nagar Haveli, Daman & Diu, Karnataka, Puducherry, Tamil Nadu

- Low levels of SO_2 , NO_2 and RSPM. States in Southern part of India are generally less polluted than Northern states.

Cluster 3: Gujarat, Maharashtra, Sikkim, Uttarakhand

- States with high SO_2 concentration.

Cluster 4: Delhi, West Bengal

- States with very high NO_2 and RSPM concentration.



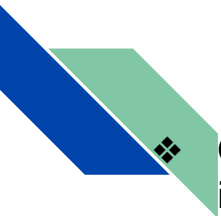
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 - ❖ Pollutant levels in states is affected by the number of vehicles and number of Industries. The seven sister states which are among the least polluted states in the country also have the least number of vehicles and factories in the country.

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- ❖ Pollution levels are surprisingly not correlated to the population density of states. For example, West Bengal and Kerala have similar population densities, but Kerala came off as one of the least polluted states in the country while West Bengal came off as one of the most polluted states in the country.

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- ❖ Pollution levels are surprisingly not correlated to the population density of states. For example, West Bengal and Kerala have similar population densities, but Kerala came off as one of the least polluted states in the country while West Bengal came off as one of the most polluted states in the country.
- ❖ The analysis also shows that pollutant levels do not follow a continuously increasing or decreasing trend in many states. For instance, the presence of the pollutant sulphur dioxide has been high from 2005 to 2008 in some states but has decreased later. Chandigarh, Daman & Diu, Dadra & Nagar Haveli are example of such states. In the initial years of analysis, Punjab has always made it to the top in terms of RSPM but later it's RSPM levels decreased and in 2014, Punjab has been categorized among the less polluted states.



Thank You