Investigating Explorative Character of Ozone Layer Depletion Between Pakistan and China: A Comparative Regional Study

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Abstract: In this communication we have assessed explorative nature of ozone layer dynamics using data of ozone depth from 1984-to 2010 at the stratospheric region of China and Pakistan. This study comprises the parametric evaluation that characterizes the physical behaviour of stratospheres of both the regions. For this purpose we have adopted exploratory data analysis (EDA). The results indicated an obvious distinction in the fluctuating dynamics of China and Pakistan. The models discussed in this communication can be used for public, private and government organizations and compared with other countries stratospheric ozone layer dynamics.

Keywords: Stratospheric Ozone layer depletion, parametric evaluation, ozone layer depletion at China and Pakistan, Ozone layer Dynamics, Exploratory Data Analysis.

I. INTRODUCTION

It is known that ozone acts as a shield for ultraviolet (UV) radiation coming from the sun. Of course it is a minor constituent of the atmosphere that plays an important role in earth biosphere. It is also evident that the changes in stratospheric and troposphere ozone contribute differently to climate variations and has different effects on this biosphere. Other variables enhance climatic changes are precipitation, temperature, humidity, CFCs, CO, CO_2, UV radiation etc. [1]. To express such activities in practical way, it is necessary to consider probabilistic models that are useful for expressing atmospheric processes such as OLD etc. [2].

Statistical analysis used extensively in atmospheric science particularly in the field of meteorology and climatology. This analysis is used to evaluate and quantify the processes as well as making inferences and forecasts.

In order to compare the explorative character of China and Pakistan atmospheric regions the current study focuses on the use of Exploratory Data Analysis (EDA), it is a powerful statistical technique to find behaviour of data and express the results descriptive parameters such as mean, variance, confident interval, standard deviation and standard error etc. [3]. For this purpose we have used Minitab and Statistica.

Ozone depths data have been taken from the Geophysical Centre Quetta, Pakistan and Chinese Academy of Science, Institute of Atmospheric Physics at Beijing, China, where Dobson Spectrophotometers have been installed under the auspices of World Meteorological Organization.

II. EXPLORATORY DATA ANALYSIS (EDA)

This analytic work has been performed using the following ingredients of EDA

(a) The histogram is a very familiar graphical tool for a single set of data. Histogram of Ozone depth data (1984-2010) for China and Pakistan regions are performed as depicted in the Figures **1a** and **1b** respectively. The area under the series of rectangles represents the frequency of each value of the ozone depth.

Figures **2a** and **2b** represent the Gaussian distribution functions for ozone depth of China and Pakistan respectively for the given period. The Gaussian distribution plays a central role in describing the behaviour of atmospheric phenomena for these two regions. The curves of the distributions as shown in figures illustrate a change. The data set for Pakistan atmospheric region has more outliers than for the China set of data.

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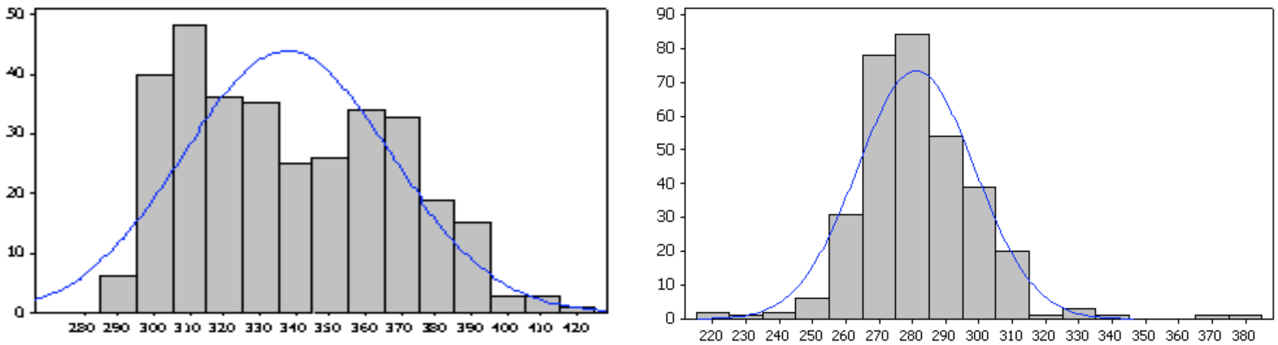
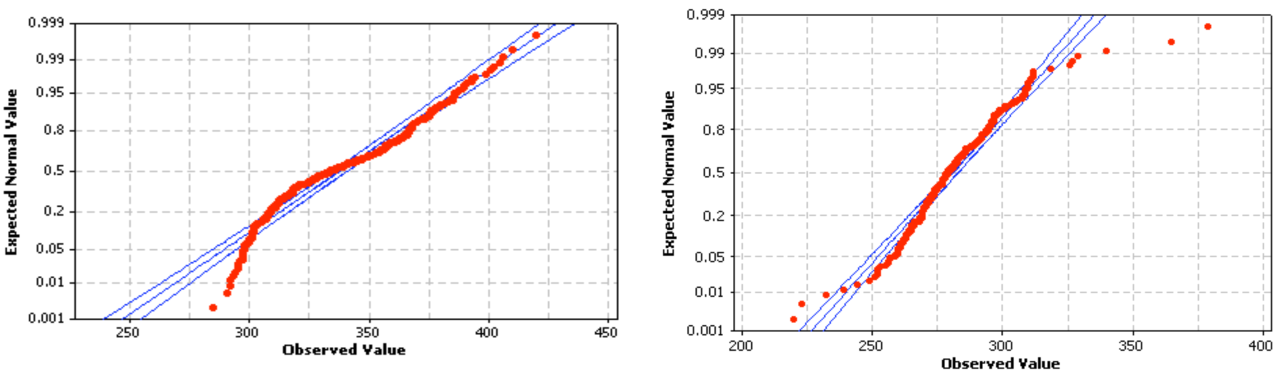


(a) (b)

Figure 1: (**a**) Histogram of ozone contents of China. (**b**) Histogram of ozone contents of Pakistan.



(a) (b)

Figure 2: (**a**) Gaussian distribution function for ozone contents of China. (**b**) Gaussian distribution functions for ozone contents of Pakistan.

The descriptive parametric values for China and Pakistan are listed in Tables **1** and **2**. Where the few parameters are compared as follows:

(a) $\bar{X}_1$ = 337.65 and σ_1 =867.32 for China, $\bar{X}_2$ = 281.11 and σ1=310.91 for Pakistan. Both sample mean and variance are the unbiased estimators of location of given distribution. The natural estimator of the difference μ_1- μ_2 is the difference between the sample means i.e.

$\bar{X}_1$ - $\bar{X}_2$ = 337.65- 281.11 = 56.54. The statistic measures the average values for China ozone depth over Pakistan. This shows unbiased estimator of the difference of population means. If both the data sets are normal distribution then the difference of $\bar{X}_1$ - $\bar{X}_2$ is also normal.

(b) Trimmed means used often in statistical analysis as robust assessment of location by making the arithmetic mean less responsive to outlier [4].

(i) 1984-2010 (N =324) for China

Trimmed mean = 336.75DU

1990-2005 (N=180)

Trimmed mean = 335.47

(ii) 1984-2010 (N=324) for Pakistan

Trimmed mean = 280.64DU

1990-2005 (N=180)

Trimmed mean = 278.05DU

Assessment of robust is the inter-quartile range which is measured by

IQ = upper quartile – lower quartile

From Table **1** parametric values for China ozone depth, the median = 334.00DU (Dobson Unit = 1×10^{-3}, 1DU = 1×10^{-3} cm), upper and lower quartiles are 362.00 and 312.00 respectively. Therefore,

Upper MAD = Upper quartile – median

For China ozone depth

Upper MAD = 362.00 - 334.00 = 28

And from Table **2** for Pakistan ozone depth, median = 279.00DU, upper and lower quartiles are 292.00 and 270.00 respectively.

Upper MAD=292.00 - 279.00 = 13.

Similarly

Lower MAD = Median – lower quartile

For China

Lower MAD = 334.00 - 312.00 = 22

For Pakistan

Lower MAD = 279.00 - 270.00 = 9

The Inter-quartile range IQ = 362.00 - 312.00 = 50 for China ozone depth and IQ = 292.00 - 270.00 = 22 for Pakistan ozone depth. This indicates China ozone depth is more spread than Pakistan ozone depth.

Table 1: Descriptive Parametric Values of Ozone Depth of China from 1984-2010 (N=324)

Parameters	Number Values
Mean ($\bar{X}_1$)	337.65
Conf. Interval (-95%)	334.43
Conf. Interval (+95%)	340.87
Median	334.00
Max.	420.00
Min.	285.00
Variance (σ_1)	867.32
Std. Dev.	029.45
Std. Error	001.63
Lower Quartile	312.00
Upper Quartile	362.00

(c) The robust method used to compute Median Absolute Deviation (MAD). It is measure of location and measure of scale. It tends to be asymptotically normal with high outlier resistance.

$$S_{MAD} = \frac{MAD}{C_{MAD}} \quad (1)$$

Table 2: Descriptive Parametric Values OF Ozone Depth for Pakistan from 1984-2010 (N=324)

Parameters	Number Values
Mean ($\bar{X}_2$)	281.11
Conf. Interval (-95%)	279.18
Conf. Interval (+95%)	283.04
Median	279.00
Max.	379.00
Min.	220.00
Variance (σ_2)	310.91
Std. Dev.	017.63
Std. Error	00.980
Lower Quartile	270.00
Upper Quartile	292.00

Where MAD can be estimated as

$$MAD = \frac{IQ}{2} \quad (2)$$

Therefore, MAD for China and Pakistan ozone depth are 25 and 11 respectively. Hence using these values we estimate S_{MAD} as 37.3 and 16.41 for China and Pakistan respectively.

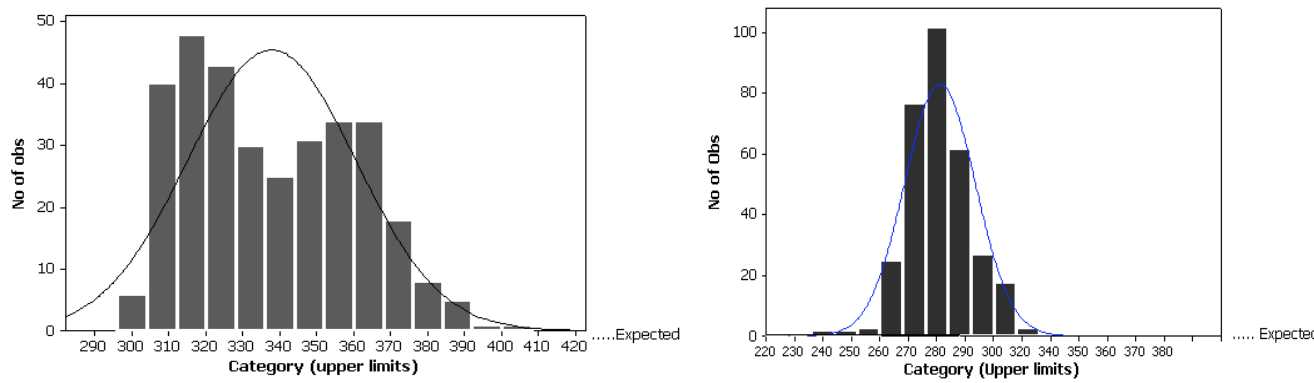
(d) To analyze whether a particular data comes from a specific probability distribution some techniques of goodness-of–fit-test are performed. i.e. Kolmogorov-Sminov (KS) Shapiro-Wilk test [5].

We have used large data sample size of n=324 for investigation and KS goodness-of-fit test has been performed to show that the population distribution of ozone depth data of China and Pakistan are normal as shown in Figures **3a** and **3b**.

For maximum absolute difference D between F_o (the cumulative observed frequency) and F_e (the cumulative expected frequency) for both regions can be obtained as

$$D = \text{maximum} \left| F_o - F_e \right| \quad (3)$$

From Table **3** and **4**, we obtained differences using equation (3) for ozone layer depletion data for China and Pakistan with maximum difference about 0.123 for China and 0.101 for Pakistan. Whereas from KS test table with level of significance α = 0.05 for sample size 324 is $D = 1.\frac{36}{\sqrt{324}} = 0.0755$. Since critical value of KS



(a) (b)

Figure 3: (**a**) Kolmogorov-Smirnov test how well the data set appears to come from normal distribution (324 observations) for China, d = 0.123. (**b**) Kolmogorov-Smirnov test how well the data set appears to come from normal distribution (324 observations) for Pakistan, d = 0.123.

Table 3: # Observations =324, # Categories =14, D_C = 0.123, Chi-Square = 5.962, df = 8, P = 0.286

# Observations	Cumulative % expected (F_e)	Cumulative Observed (F_o)
290	0.00	0.308
300	0.31	8.024
310**	10.18	22.530
320	29.32	38.271
330	44.44	46.913
340	56.17	55.555
350	65.74	62.654
360	79.32	72.839
370	91.35	85.185
380	96.91	91.975
390	99.07	96.604
400	99.69	98.148
410	100.00	99.691
Infinity	100.00	100.00

test is D = 0.075 and observed values for China and Pakistan are 0.123 and 0.101 respectively. Critical value is less than observed values of both regions so we reject null H_o.

(e) Coefficient of Variation (CV) is one of the measures that described the scatter of the distribution relative to the size of the estimated mean and the diversity of the data from normalit [6]. It indicates stability and consistency of the data and is given by [7]

C_V = Standard Deviation / Mean

CVs for computed descriptive parameters given in Tables **1** and **2** are 0.087 and 0.063. This indicates good normality.

III. HYPOTHESIS TESTING

Hypothesis testing tells us how data are used to decide whether to accept or reject an assumption about the parametric values. We have tested the hypothesis for μ is greater than 337.65DU or less than 337.65DU for China ozone depth and greater than 281.11DU of less than 281.11DU for Pakistan ozone depth. If observed t value is less than critical value then H_o accepted and rejected if it is greater than critical vale.

Different sample sizes of 48 observations (1984-1987), 192 observations (1990-2006) and 204 observations (1990-2007) have been selected to test both data set of China and Pakistan ozone depth.

Table 4: # Observations =324, # Categories =17, D_P = 0.1018, Chi-Square = 9.15403, df = 5, P = 0.109

# Observations	Cumulative % expected (F_e)	Cumulative Observed (F_o)
220	0.000	0.308
230	0.000	0.617
240	0.309	1.234
250	0.926	1.851
260	2.160	7.098
270**	15.123	25.308
280	52.778	53.703
290	78.704	73.148
300	92.593	89.506
310	98.148	96.296
320	99.074	98.148
330	99.383	99.074
340	99.383	99.382
350	99.691	99.382
360	100.00	99.382
370	100.00	99.691
Infinity	100.00	100.00

95% confidence level for China ozone depth.

(i) Sample size n = 48 , μ = 337.77 DU

1. Let H_o: μ = 337.77 H_1: μ ≠ 337.77

2. The test statistic is t

3. Significance level α = 0.05 and critical value of t = ± 2.021 with degree of freedom 47

4. True value of t is -0.07 with sample mean is 337.77 DU and sample standard deviation S_1 =32.05

5. Our observed t value -0.025 is low and out of critical region so we accept H_o: μ = 337.77

95% confidence level for Pakistan ozone depth

(i) Sample size n = 48 with μ = 278.83DU

1. Let H_o: μ = 278.83 H_1: μ ≠ 278.83

2. The test statistic is t

3. Significance level α = 0.05 and critical value of t = ± 2.021 with degree of freedom 47

4. True value of t is -1.12 with sample mean is 278.83 DU and sample standard deviation S_1=14.03

5. Our observed t value -1.12 is low and out of critical region so we accept H_o: μ = 337.77

IV. CONCLUSIONS

In this study we have presented a comparative aspect of stratospheric ozone layer depletion for China and Pakistan atmospheric regions. For this purpose we have utilized rigorously Exploratory Data Analysis (EDA). We have computed all the parameters and developed models for both the regions. These strategies are used for explorative character of ozone layer depletion between Pakistan and china provided an inclusive explanation of the process. Our distinguished results from all the sections of this paper depicted that the China ozone layer dynamics is more broaden than Pakistan ozone layer depletion dynamics. Trimmed means used often in statistical analysis as robust assessment of location is larger for China than for Pakistan that manifests that ozone layer depletion rate is more in China.

Similarly, hypothesis tests showed the null hypothesis has been accepted for China and Pakistan atmospheric regions. Thus we can also compare the explorative behaviour of ozone layer depletion with other countries like Turkey, Egypt, Indonesia, Malaysia and Saudi Arabia etc.

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