Emission dynamics of some green house gases and criteria pollutants in Indian perspective

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Abstract— Global warming is a serious phenomenon for the last few decades to confront human society. Unwanted emissions of green house gases are solely responsible for this situation. Criteria pollutants are also important for the atmospheric chemistry of green house gases. Increased emission of global warming gases like carbon dioxide, methane and nitrous oxide and criteria pollutants such as sulphur dioxide, nitrogen oxides and carbon monoxide from different sources to the environment is much alarming. In this paper, an attempt has been made to identify the pattern of emission of the mentioned gases in Indian perspective. A statistical approach, namely least square method is applied for the development of the model utilizing the data set of hundred years in India. Diagnostic tools namely, coefficient of determination and residual analysis that ensure the quality of the proposed model yields noteworthy results. In this paper, a prediction of the above mentioned gases are made for a period of 25 years. A precautionary measure to curb the superfluous emission of the gases can be undertaken in this connection.

Keywords*- Global warming; Green house gases; Criteria pollutants; Least square method; Coefficient of determination; Residual analysis.*

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I. INTRODUCTION

Technological, industrial and agricultural development along with population growth throughout the world including India has augmented environmental degradation. Rapid urbanization results mounting cities, more traffic on roads, increasing energy consumption along with waste production which ultimately alters the chemical composition of the atmosphere. These phenomenons lead to undesirable emission of different green house gases associated with criteria pollutants which cause global warming. Global warming is one of the important and burning issues in the present world. India is also facing the same problem related to climate change associated with global warming. The main reason for the environmental degradation along with gradual increase of temperature worldwide is the unrestricted emission of green house gases mainly carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Criteria pollutants like carbon monoxide (CO), sulphur dioxide (SO_2) and nitrogen oxides (NO_x = NO+NO_2) associated with green house gases are also responsible for changing the composition of the atmosphere [1,2,3]. In India, the increase in temperature counts on fossil fuels, including coal, coke, coke oven gas, crude oil and also sustainment of green house gases and criteria pollutants in the atmosphere [4,5,6].

Emission of green house gases and criteria pollutants from different source mainly depends on industrialization, urbanization and economic growth. Several researchers identified different sources of unwanted emissions of these gases in different sectors. Singh et *al*. [7] elaborated the trends of energy consumption and consequent emissions of green house gases from the road transport sector in India. Efforts are made to study the nature of change of CO_2 emission and its constituents. Kram et *al*. [8] studied global and regional greenhouse gas emissions scenarios and introduced key sources and parameters in emissions. Similarity research and results obtained by Fenhann [9] to study on industrial non-energy resources for green house gases. Ritter et *al*. [10] recommended methodologies for consistent estimation of green house gases emissions from oil and gas industry facilities. Parikh et *al*. [11] described CO_2 emission structure of Indian economy based on fuel type, sector wise, final demand and expenditure classes. Regarding CH_4 emission, paddy fields are considered to be one of the important anthropogenic sources of atmospheric CH_4. CH_4 emission from paddy fields, which depend on many factors [12,13,14] arises due to the anaerobic decomposition of organic materials in the flooded soil and escapes to the atmosphere mainly by diffusive transport through the paddy plants [15] during the growing season. Forecasting of N_2O which is an environment pollutant gas was studied by researchers [16].

Criteria pollutants like CO forms primarily when carbon fuels are not burned completely. Mobile sources account for the majority of CO emission [17]. These sources include both on-road vehicles and no-road vehicles and engine equipment. Consequently, high concentration of CO generally occurs in areas with heavy traffic congestion. In short, as much as 95% of all CO emission may come from automobile exhaust [17,18]. SO_2 pollutes the environment very fast and leads to certain secondary products [19]. The use of fuel wood alone in India is predicted to increase by a factor of three from 1985 to 2015 [20]. Increased energy use will result in a large increase of SO_2 and NOx emissions leading to regional increase in precursors to acid deposition, tropospheric ozone and ambient aerosols. Bhattacharya and Mitra [21] reported that 109 Gg NOx as NO_2 is contributed from biomass burning in India.

Mathematical modelling for the emission and future prediction of different atmospheric gases has been studied by several researchers. Among the various modelling methods, Artificial Neural Network (ANN) and multiple regression analysis are utilized for forecast of SO_2 [19,22,23]. The techniques such as ANN, structural time series are applied to quantify the concentration of nitrogen oxides [24,25,26]. Other studies reveal that structural time series based approach and response surface methodology was also applicable in predicting concentration of NO_x [27,28]. Regression analysis is also applied in finding estimation of concentration of N_2O in a thermal power plant [29]. In addition, investigations were performed for the forecast of air quality in search of pollution using various statistical techniques and data driven approach [30,31].

In this paper, the authors formulated a dynamical model of the three green house gases and three criteria pollutants from the data set of about100 years from 1890-1985[32]. The solution for model for each of the gases has been solved by least square regression method. Thereafter, the computation of Instantaneous rate of change (IROC) leads to future prediction of emission of the above mentioned gases.

II. Methodology

A. Analytical development

Evolutionary mathematical model of emission of the mentioned green house gases and criteria pollutants are developed in the present methodology in Indian perspective. Denoting E to be the total emission of three green house gases and other criteria pollutants, the systematic representation of the gases is given in the form

$$\frac{dE}{dt} = f\left(\frac{dA}{dt}, \frac{dB}{dt}, \frac{dC}{dt}, \frac{dD}{dt}, \frac{dE}{dt}, \frac{dF}{dt}\right) \quad \ldots\ldots\ldots\ldots\ldots(1)$$

where A, B, C, D, E and F are the emission of CO_2, CH_4, N_2O, CO, SO_2 and NO_X respectively. Without any loss of generosity, the present paper established a model of green house gases and criteria pollutants emission by

$$\frac{dE}{dt} = c1\frac{dA}{dx} + c2\frac{dB}{dx} + c3\frac{dC}{dx} + c4\frac{dD}{dx} + c5\frac{dE}{dx} + c6\frac{dF}{dx} + c7 \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where c1 to c6 represent the coefficients of each differential term and c7 is a constant. In order to generate mathematical model of green house gases and other pollutant gases in Indian perspective, we visualize different sources of green house gases and criteria pollutants. The works of Tokos [32], Xi Nung [33], Nandi and Basak [34] suggested a third degree polynomial model for one of the major constituent green house gases. Anticipating a similar characteristics for other green house and pollutant gases supported, in our model, a third degree polynomial is fitted for the emission of the constituent gases, namely

$$Y = a + b.x + c.x^2 + d.x^3 \quad \text{---------------------(3)}$$

where Y is the emission of gas and x represents time in years.

B. Least Square Method

Given data (x_1,y_1), (x_2,y_2),…,(x_N,y_N) , an error associated may be presented as

$$E(a, b, c, d) = \Sigma (y_i - a - bx_i - cx_i^2 - dx_i^3)^2 \quad \ldots\ldots\ldots\ldots(4)$$

The equation (4) is the N times variance of the data set (error) $\{y_1 - (a + bx_1 + cx_1^2 + dx_1^3),\ldots, y_N - (a + bx_N + cx_N^2 + dx_N^3)$ and is a function of four variables a, b, c and d. The goal is to estimate a, b, c and d with a view to minimize the error. Equating to zero, the partial derivatives with respect to a, b, c, d can be written as

$$\frac{\partial E}{\partial a} = 0 = -2\sum (y_i - a - bx_i - cx_i^2 - dx_i^3)$$

$$\frac{\partial E}{\partial b} = 0 = -2\sum x_i(y_i - a - bx_i - cx_i^2 - dx_i^3)$$

$$\frac{\partial E}{\partial c} = 0 = -2\sum x_i^2(y_i - a - bx_i - cx_i^2 - dx_i^3)$$

$$\frac{\partial E}{\partial d} = 0 = -2\sum x_i^3(y_i - a - bx_i - cx_i^2 - dx_i^3)$$

The corresponding normal equations are

$$\sum y_i = na + b\Sigma x_i + c\Sigma x_i^2 + d\Sigma x_i^3$$

$$\sum x_i y_i = a\Sigma x_i + b\Sigma x_i^2 + c\Sigma x_i^3 + d\Sigma x_i^4$$

$$\sum x_i^2 y_i = a\Sigma x_i^2 + b\Sigma x_i^3 + c\Sigma x_i^4 + d\Sigma x_i^5$$

$$\sum x_i^3 y_i = a\Sigma x_i^3 + b\Sigma x_i^4 + c\Sigma x_i^5 + d\Sigma x_i^6 \quad \ldots\ldots(5)$$

For given set of points (x_i, y_i); (i=1,2,…,N), the equation (5) can be solved for a, b, c, d which is the third degree polynomial best fit. It has been observed that in all the cases, the values of the 2^{nd} order partial derivatives w.r.t a, b, c, d come out to be positive indicating minimization of E. Thus, the third degree fitted polynomial of the concerned gas emission is estimated as

$$Y = a^\# + b^\#.x + c^\#.x^2 + d^\#.x^3 \quad \ldots\ldots(6)$$

where # represents corresponding estimated values.

C. Instantaneous rate of change

In order to compute the rate of change of the gas, the derivative of equation (6) can be represented as

$$dY/dx = b^\# + 2c^\#.x + 3d^\#.x^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

The equation (7) is utilized for the prediction of the concerned gas at a particular time.

III. Results and Discussions

A. Analysis of emission of CO_2, CH_4 and N_2O

For the analysis of emission of green house gases, the dynamic models utilizing the data set of about hundred years in India are expressed in the following way

$$Y_{CO2} = 23713.918 - 3.8841x - 0.0155x^2 + 5.7817E\text{-}006.x^3 \quad \ldots..(8a)$$

$$Y_{CH4} = 156.8495 - 0.0281x - 0.00010.x^2 + 4.2067E\text{-}8.x^3 \quad \ldots\ldots(8b)$$

$$Y_{N2O} = 78.7598 - 0.0127x - 5.1582E\text{-}5x^2 + 1.9267E\text{-}3.x^3 \quad \ldots\ldots.(8c)$$

where x represents time in years.

A graphical display of the actual data and the solution of the above models by least square method are given in Fig. 1a, 1b and 1c for CO_2, CH_4 and N_2O respectively. This shows that India's major green house gas emissions have a power series growing trend.

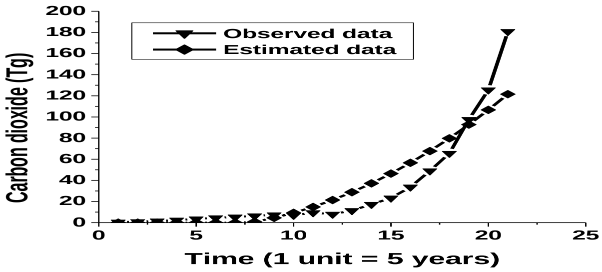

Fig. 1a Carbon dioxide emission

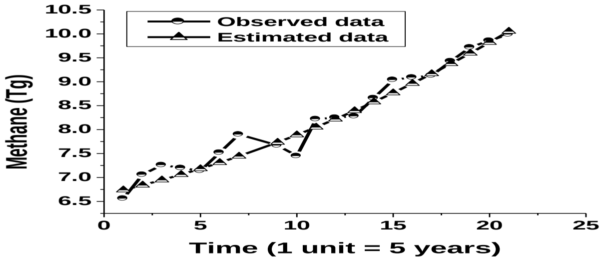

Fig. 1b Methane emission

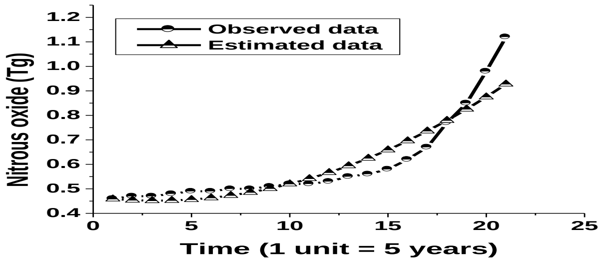

Fig. 1c Nitrous oxide emission

In Fig.1a, we observe the CO_2 emission in India have obvious classes representing from smooth nominal growth to rapid growth last from 1890 to 1985. This represents overall picture of emission and indicates significant and rapid growth of India's energy consumption. The rapid growth in recent years leads to rapid consumption of fuels in automobiles and industry. Also, we find that our CO_2 emission dynamic model matches well with the actual status of the carbon dioxide emission. Fig. 1b represents the emission of CH_4 for actual data (for the same period) and model data and it also matches well. We can observe from the Fig. 1b that an overall increasing trend occurred except a drop of emission around 1920 and 1930. Fig. 1c represents the comparative results of N_2O for observed and estimated results. The actual observation data indicates an exponential growth from 1940. A similarity between observed and model data is indicated. In order to test the quality of the proposed analytical models, the values of R^2 (R^2 adjusted) are computed and presented in Table 1. The value of R^2 (R^2 adjusted) reflect the fact that we have identified a good model for the gases CO_2, CH_4 and N_2O.

TABLE 1. STATISTICAL EVALUATION CRITERIA

Green house gases	R^2	R^2 adjusted
CO_2	0.8534	0.8275
CH_4	0.9142	0.8990
N_2O	0.8584	0.8335

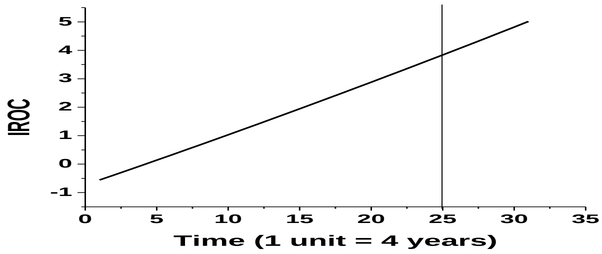

Fig.2a IROC of carbon dioxide

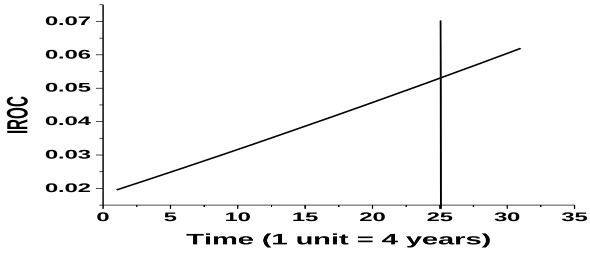

Fig.2b IROC of methane

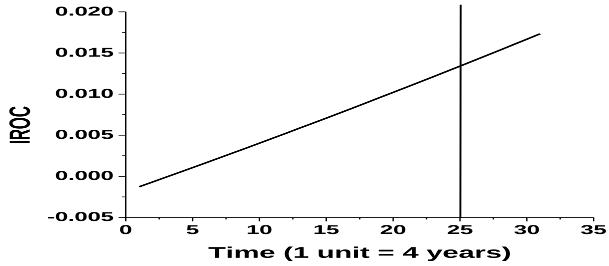

Fig. 2c IROC of nitrous oxide

B. *IROC of emission of CO_2, CH_4 and N_2O*

IROC of emission of gases is helpful for the prediction of future emission. Here, IROC of CO_2, CH_4 and N_2O emission as a function of time can be expressed analytically by

$$dy/dx(CO_2)=-3.8841–0.03102.x+0.000017.x^2 \quad \ldots\ldots (9a)$$

$$dy/dx(CH_4)=-0.0281–0.00021x+0.00000012.x^2 \quad \ldots\ldots. (9b)$$

$$dy/dx(N_2O)=-0.0127–0.00010.x+0.0057.x^2 \ldots \ldots\ldots.. \quad (9c)$$

A graphical display of IROC vs time of the three green house gases is shown in Fig. 2a, 2b and 2c. From these Figures it is possible to estimate the rate of change of CO_2, CH_4 and N_2O emission in India from where prediction can be done for short and long term of time. The vertical lines in the Figures indicate completion of hundred years estimated IROC values for the above three gases beyond which prediction is possible. Now, for the emission of CO_2 in India, the empirical rate of change, the instantaneous rate of change using the developed differential equation, DF IROC along with the residual being the difference of the two have been presented in Table 2. It has been observed from the table that the residuals are small and also the standard error. This certainly indicates that we have identified a good model for emission of CO_2. From Fig. 2a emission prediction for CO_2 in India for the year 2020, 2030 and 2040 are 230.9173, 275.1341 and 323.2881 Tg (Teragram) respectively.

TABLE 2: THE RESIDUAL ANALYSIS FOR CO_2

Year	Empirical IROC	DF IROC	Residual
1890	0.7547	2.0825	-1.3278
1895	0.6989	0.4277	0.2712
1900	0.5063	0.1235	0.3827
1905	0.4831	-0.0461	0.5293
1910	0.2946	-0.2137	0.50833
1915	0.1706	-0.4827	0.6534
1920	0.2018	-1.3425	1.5444
1925	0.1430	5.1258	-4.9827
1930	-0.0571	1.0337	-1.0908
1935	0.3636	0.6057	-0.2421
1940	-0.1555	0.4381	-0.5937
1945	0.4385	0.3472	0.0912
1950	0.5069	0.2895	0.2174
1955	0.3485	0.2492	0.0992
1960	0.4440	0.2194	0.2246
1965	0.4550	0.1963	0.2586
1970	0.3382	0.1779	0.1603
1975	0.4884	0.1628	0.3256
1980	0.2863	0.1501	0.1362
1985	0.4398	0.1394	0.3004
Mean of Residual			0.1207
Std. Dev. of Residual			1.2625
Std. Error of Residual			0.2823

Table 3 represents the empirical IROC, DF IROC and the residual analysis for the emission of CH_4 in India. As seen from the table, the residuals and the corresponding standard error are extremely small leading to identification of a good model. Furthermore, we predict instantaneous variation of CH_4 emissions in India in Medium-short term range. Again from Fig. 2b emission prediction for CH_4 in India for the year 2020, 2030 and 2040 are 11.6, 12.17 and 12.77 Tg respectively.
Similarly Table 4 represents the empirical IROC, DF IROC and the residual analysis for the emission of N_2O in India. Extremely small residuals identified a good model for the gas N_2O and from Fig. 2c emission prediction for N_2O in India for the year 2020, 2030 and 2040 are 1.31, 1.46 and 1.63 Tg respectively.

TABLE 3: THE RESIDUAL ANALYSIS FOR CH_4

Year	Empirical IROC	DF IROC	Residual
1890	0.0762	0.0149	0.0612
1895	0.0283	0.0157	0.0125
1900	-0.0082	0.0164	-0.0247
1905	-0.0083	0.0171	-0.0254
1910	0.0532	0.0177	0.0354
1915	0.0505	0.0183	0.0321
1920	-0.0772	0.0189	0.0961
1925	-0.0850	0.0195	-0.1045
1930	0.1169	0.0200	0.0969
1935	0.1033	0.0205	0.0828
1940	0.0036	0.0209	-0.0173
1945	0.0036	0.0213	-0.0177
1950	0.0458	0.0217	0.0241
1955	0.0438	0.0221	0.0217
1960	0.0055	0.0224	-0.0168
1965	0.0044	0.0227	-0.0183
1970	0.0328	0.0229	0.0098
1975	0.0307	0.0232	0.0075
1980	0.0144	0.0234	-0.0090
1985	0.0132	0.0236	-0.0105
Mean of Residual			0.0020
Std. Dev. of Residual			0.0481
Std. Error of Residual			0.0107

TABLE 4: THE RESIDUAL ANALYSIS FOR N_2O

Year	Empirical IROC	DF IROC	Residual
1890	0.0217	-0.0106	0.0324
1895	0.0000	-0.0044	0.0044
1900	0.0212	0.0020	0.0192
1905	0.0208	0.0084	0.0123
1910	0	0.0148	-0.0148
1915	0.0204	0.0210	-0.0006
1920	0	0.0268	-0.0268
1925	0.0199	0.0323	-0.0123
1930	0.0196	0.0372	-0.0176
1935	0	0.0417	-0.0417
1940	0.0192	0.0456	-0.0264
1945	0.0377	0.0490	-0.0113
1950	0.0181	0.0518	-0.0337
1955	0.0357	0.0542	-0.0185
1960	0.0689	0.0561	0.0128
1965	0.0806	0.0576	0.0230
1970	0	0.0587	-0.0587
1975	0.2686	0.0594	0.2091
1980	0.1529	0.0599	0.0930
1985	0.1428	0.0601	0.0827
Mean of Residual			0.0324
Std. Dev. of Residual			0.0044
Std. Error of Residual			0.0192

C. Analysis of emission of SO_2, NO_x and CO

For the analysis of emission of criteria pollutants in the atmosphere, the emission models based on about hundred years of data in India may be represented as

$$Y_{SO2}=306.5340-0.0591x-0.0002x^2+7.9326E-8x^3 \quad .....(10a)$$

$$Y_{NOx}=627.6795-0.1068x-0.00041x^2+1.5471E-7x^3 \quad .....(10b)$$

$$Y_{CO}=5787.2031-1.0726x-0.0038x^2+1.4681E-6x^3 \quad .....(10c)$$

where x represents time in years.

A graphical display of the observed data and the solution of the above models for the emission of criteria pollutants SO_2, NO_x and CO by least square method are given in Fig. 3a, 3b and 3c which represent the comparative emission graph.
In Fig. 3a, we can observe the SO_2 emission in India has specific classes representing from smooth nominal growth to rapid growth with fluctuation. This picture represents the growth of India's energy consumption. Fig. 3b and 3c show an excellent similarity between the observed data and solution of our model i.e. estimated results. Increasing trend of emission proves rapid increase of industrialization along with increased use of automobiles.

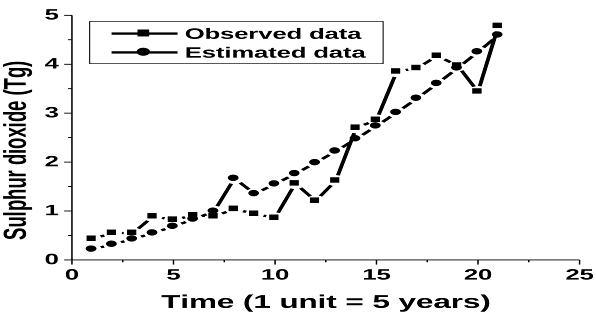

Fig. 3a Sulphur dioxide emission

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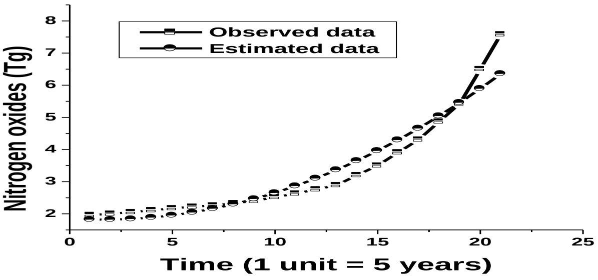

Fig. 3b Nitrogen oxides emission

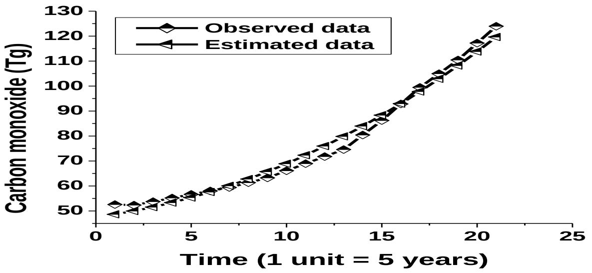

Fig. 3c Carbon monoxide emission

In order to test the quality of the proposed analytical models, the values of R^2 (R^2 adjusted) are computed and presented in Table 5. It has been observed from the Table that values of R^2 are 0.9041, 0.9355 and 0.9840 for SO_2, NO_x and CO respectively which is excellent. These results indicate good identification of presented models for the gases SO_2, NO_x and CO.

D. IROC of emission of SO_2, NO_x and CO

IROC for the emission of criteria pollutants e.g. SO_2, NO_x and CO as a function of time have been calculated and can be expressed analytically by

$$dy/dx(SO_2) = -0.0591 – 0.00040.x + 0.00000023797.x^2 \ldots(11a)$$

$$dy/dx(NO_x) = -0.1068 – 0.0008.x + 0.00000046413.\ x^2 \ldots\ldots(11b)$$

$$dy/dx(CO) = -0.072 – 0.00076.x + 0.0000004404 \quad \ldots\ldots..(11c)$$

11a, 11b and 11c represent the IROC emission equation of SO_2, NO_x and CO respectively. From these equations, the graphical display of IROC of the criteria pollutants, SO_2, NO_x and CO as a function of time can be presented in Fig. 4a, 4b and 4c respectively. Future estimation for the emission of SO_2, NO_x and CO in India can be done from these Figures for short and long term of time. The vertical lines in the Figures indicate completion of hundred years of estimated IROC values for the above three gases. Now, if we go beyond the vertical lines, we can easily predict the future IROC for these gases from where the future emission of the criteria pollutants can be done for short and long range of time in Indian perspective. From Fig. 4a, emission prediction for the criteria pollutant SO_2 in India for the year 2020, 2030 and 2040 are 6.933, 7.823 and 8.769 Tg respectively. Similarly from Fig. 4b, it can be predicted that emission of NO_x in India for the year 2020, 2030 and 2040 are 9.6737, 10.9889 and 12.4102 Tg respectively.

TABLE 5. STATISTICAL EVALUATION CRITERIA

Green house gases	R^2	R^2 adjusted
SO_2	0.9041	0.8872
NO_x	0.9355	0.9241
CO	0.9840	0.0159

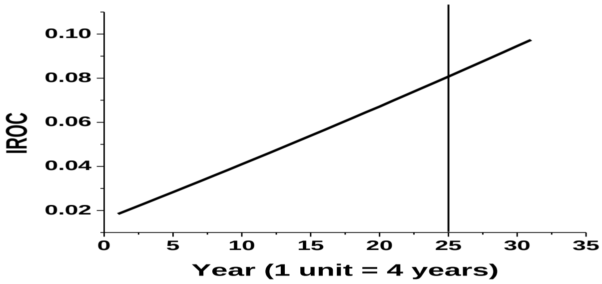

Fig. 4a IROC of Sulphur dioxide

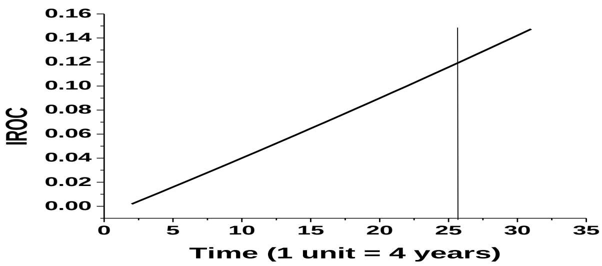

Fig. 4b IROC of Nitrogen oxides

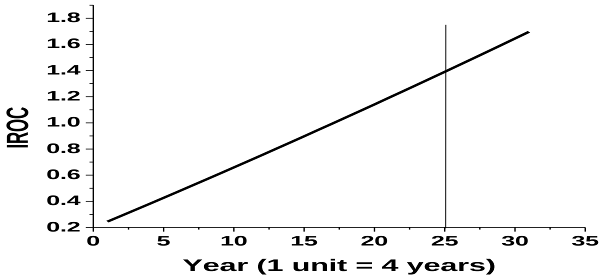

Fig. 4c IROC of Carbon monoxide

From Fig. 4c, the prediction of emission of CO are 159.8669, 175.2935, 191.7448 Tg for the year 2020, 2030 and 2040 respectively.

Now, the empirical rate of change, the instantaneous rate of change and the residual for the emission of SO_2, NO_x and CO using the developed differential equation 11a, 11b and 11c have been presented in Table 6, 7 and 8 respectively. From Table 6, it has been observed that the residual and the standard error are small which indicates good identification of mathematical model for the emission of SO_2 in India.

Table 7 indicates the values of IROC, DF IROC and the residuals from where we can observe the small values of residuals in case of emission of NO_x in India. So, also a good model has been identified. Similarly, residual analysis obtained from Table 8 indicates quality mode for the emission of CO in India. Thus, IROC values have an important role for the prediction of emission of green house gases as well as criteria pollutants in future in Indian perspective.

TABLE 6: THE RESIDUAL ANALYSIS FOR SO_2

Year	Empirical IROC	DF IROC	Residual
1890	0.2790	0.4508	0.1717
1895	0.0	0.3496	-0.3496
1900	0.6182	0.2882	0.3299
1905	-0.0786	0.2463	-0.3249
1910	0.1097	0.2159	-0.1061
1915	-0.0219	0.1926	-0.2146
1920	0.1685	0.1742	-0.0056
1925	-0.0961	0.1593	-0.2554
1930	-0.0851	0.1468	-0.2319
1935	0.8139	0.1362	0.6776
1940	-0.2243	0.1272	-0.3512
1945	0.3388	0.1193	0.2194
1950	0.6667	0.1124	0.5542
1955	0.0592	0.1064	-0.0471
1960	0.3461	0.1009	0.2452
1965	0.0182	0.0961	-0.07789
1970	0.0638	0.0916	-0.0279
1975	-0.0479	0.0876	-0.1356
1980	-0.1335	0.0840	-0.2175
1985	0.3895	0.0806	0.3089
Mean of Residual			-0.0087
Std. Dev. of Residual			0.2923
Std. Error of Residual			0.0654

TABLE 8: THE RESIDUAL ANALYSIS FOR CO

Year	Empirical IROC	DF IROC	Residual
1890	-0.0119	0.0275	-0.0393
1895	0.0266	0.0312	-0.0048
1900	0.0272	0.0347	-0.0075
1905	0.0264	0.0378	-0.0114
1910	0.0242	0.0406	-0.0164
1915	0.0236	0.0430	-0.0194
1920	0.0325	0.0451	-0.0126
1925	0.0313	0.0469	-0.0156
1930	0.0452	0.0484	-0.0031
1935	0.0452	0.0484	-0.0031
1940	0.0433	0.0495	-0.0063
1945	0.0409	0.0505	-0.0096
1950	0.0393	0.0512	-0.0119
1955	0.0779	0.0517	0.0262
1960	0.0724	0.0520	0.0204
1965	0.0769	0.0521	0.0247
1970	0.0715	0.0522	0.0193
1975	0.0551	0.0521	0.0030
1980	0.0522	0.0519	0.0003
1985	0.0612	0.0516	0.0096
Mean of Residual			-0.0023
Std. Dev. of Residual			0.0161
Std. Error of Residual			0.0036

I. CONCLUSION

The present study deals with the emission of three green gases such as carbon dioxide, methane and nitrous oxide and three criteria pollutants such as sulphur dioxide, nitrogen oxides and carbon monoxide in Indian perspective. Utilizing the data set of about hundred years, analytical models of the gases using least square method have been estimated which characterize the emission behavior in environment. Moreover, statistical procedures like coefficient of determination (R^2 and adjusted R^2) have been applied to investigate the goodness of the proposed models.

TABLE 7: THE RESIDUAL ANALYSIS FOR NO_x

Year	Empirical IROC	DF IROC	Residual
1890	0.0204	-0.0012	0.02168
1895	0.0249	0.0115	0.0134
1900	0.0293	0.0243	0.0049
1905	0.0284	0.0362	-0.0078
1910	0.0230	0.0471	-0.0241
1915	0.0180	0.0567	-0.0387
1920	0.0310	0.0647	-0.0338
1925	0.0300	0.0713	-0.0412
1930	0.0499	0.0764	-0.0264
1935	0.0436	0.0801	-0.0365
1940	0.0494	0.0827	-0.0333
1945	0.0471	0.0843	-0.0372
1950	0.1073	0.0851	0.0221
1955	0.0937	0.0852	0.0085
1960	0.1171	0.0848	0.0323
1965	0.1023	0.0840	0.0183
1970	0.1299	0.0829	0.0470
1975	0.1150	0.0816	0.0334
1980	0.1970	0.0800	0.1169
1985	0.1661	0.0785	0.0876
Mean of Residual			0.0061
Std. Dev. of Residual			0.0424
Std. Error of Residual			0.0095

Computation of instantaneous rate of variation from observed and estimated results and its residuals also support the identification of good models. Lastly, predictions of the emission of green house gases and criteria pollutants in Indian perspective are made from our statistical results. Our study may be helpful for the future researchers to predict the emission of other harmful gases in environment from different sources from where preventive measures can be taken to curb the unwanted emission in future.

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