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Article

Modelling the Global Mean Temperature

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Abstract

Reality has it been that over the last decade a substantial rise in population along with the corresponding energy demand has increased the concentration of green-house gases in the atmosphere. The above two phenomena have left their major cumulative adverse consequences, being reflected, in terms of an increase in the concentration of the direct (CO_2) and indirect (NO, SO_2, CO) green-house gases over the years. It is needless to mention that these above-mentioned systematic changes have ultimately manifested themselves in terms of the menacing global warming phenomenon. The phenomena, “the melting of land ice and the simultaneous thermal expansion,” have left their subsequent marks to play the prime cause of the global sea-level rise, and, indeed, rigorous analytical studies/researches on this aspect have confirmed that the average rise in sea-level globally stands at the rate of 2mm per year in conjunction with an increase in the global surface temperature of 0.74 ± 0.18°C (1.33 ± 0.32°F). The above message, however, follows from the content of the 2007 fourth assessment report by the Intergovernmental Panel on Climate Change (IPCC) (see Section 2). This paper presents research findings in regard to the global warming phenomenon, based on the development of the parametric and non-parametric models providing medium to high precision levels, so to say, to enrich our wisdom on the extent of change in the global average temperature over the recent years.

Key Words: Global warming, Green-house gases, Parametric and non-parametric modelling

1. Introduction

It is no denying that the global warming is the most dreaded phenomenon of the present time being created by the injudicious actions perpetrated to interfere in (or disturb) the natural ways governing the balance of the environment essential for the sustenance of the life in this abode, called the mother earth. A peep into the data on the annual global average temperature will reveal the existence of the unerring presence of a steady increasing trend in it. Indeed, a thorough examination of the data on the global average temperature over the last 132 years (1880–2011), data source mentioned in Section 2, has clearly exhibited a steady increase in the absolute mean global temperature computed at different periods comprising varying number of years over the above entire time span. To be more specific, the said period of 132 years can be partitioned basically into three main time-periods, 1880–1936, 1937–1980 and 1981–2011, based on the temperature variation pattern. An analysis of the temperature-record reveals the following: (a) during the time-period, 1880–1936, the mean absolute global temperature was around 13.77 degree centigrade which marginally increased to 14 degree centigrade during the time-period 1937–1980; (b) the standard deviations of annual mean global temperature during both the time-periods, 1880–1936 and 1937–1980, were almost

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the same (0.09913 for 1880–1936 during 57-year period and 0.09314 for 1937–1980 during 44-year period); and however, (c) the change was remarkable during the short time period 1981–2011 (last 31 years), wherein the mean absolute temperature rose up to 14.41 degree centigrade, and the variation in the mean absolute temperature observed during this period was also found to be very much noteworthy (with standard deviation 0.155). The above revelation has been summarised in

Table 1

Time period	Mean absolute temperature	Standard deviation
1880–1936	13.7739	0.09913
1937–1980	14.0086	0.09314
1981–2009	14.415	0.15500

Table 1.

From what has been mentioned above (also Table 1), it is clear that the extent of variation existing in the global mean absolute temperature is substantially greater in the third period (31 years from 1981–2011), and thus it appears most appropriate to model the global temperature in the said period. Towards this effort we have called upon the parametric, non-parametric and semi-parametric models to represent the pattern existing in the global mean absolute temperature in the third period. As revealed from Table 3, the Spline and Loess models provide relatively more precise fits (as the values of the R-square coefficient for these models are much more than those of other models examined in this paper). In fact, it is well-known from statistical literature that the value of the R-square coefficient indicates the level of precision with respect to a given tested model. Indeed, it also speaks about the degree of closeness of the tested model with the data on which the model is fitted. A high value of R-square (very close to one) indicates a very good fit, so to say, implying that the level of precision is very high.

2. Materials and Methods

The data sources are:

IPCC Report 2007 –
http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml#1

Temperature Data Source –
http://data.giss.nasa.gov/gistemp/tabledata_v3/GLB.Ts+dSST.txt

Among the parametric models, polynomial models (up to order 8, graphs being differentiated using 8 distinct colours, indeed, graph with respect to each order is displayed by a particular distinct colour) have been tried but as revealed from Table 2, the values of R-square coefficient exhibit only tiny increase (of the order, less than 0.03), when models involving orders higher than the quadratic are used. Thus in the final Table 3, results corresponding to polynomials, linear and quadratic only, have been given. The graph plot is also presented below.

POLYNOMIAL FIT

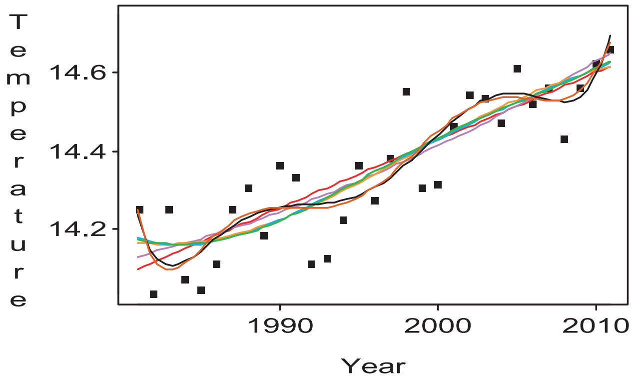


Table 2

Curve	Degree(Polynomial)	Model DF	Model Mean Square	Error DF	Error Mean Square	R-Square
red	1	1	0.5785	29	0.0094	0.7372
purple	2	2	0.2916	28	0.0094	0.745
orange	3	3	0.2001	27	0.0093	0.7521
cyan	4	4	0.1506	26	0.0101	0.759
green	5	5	0.1221	25	0.0102	0.7651
black	6	6	0.1056	24	0.0104	0.7633
orange	7	7	0.0906	23	0.0100	0.7701
blue	8	8	0.0793	22	0.0096	0.7702

Parametric Regression Fit

As will be mentioned below, Table 3 includes the values of R-square coefficient corresponding to the quadratic model only, apart from the non-parametric models, Kernel and Loess and the semi-parametric model, Spline. Indeed, the non-parametric and semi-parametric models are widely known, however, detailed ramifications of such models can be found in, Thisted (1988), Simonoff (1996), Hardle et al. (2004), very brief reviews in Kageyama et al. (2006), and Pal et al. (2012). Following the general usage of representation, "Y" and "X" denote the "Yearly mean absolute global temperature" and "Year" respectively.

3. Results and Discussion

The following Table 3 records the values of the R-square coefficient for the precise models presented here. It is observed that Loess and Spline models give better fits as precision-levels for these models are higher.

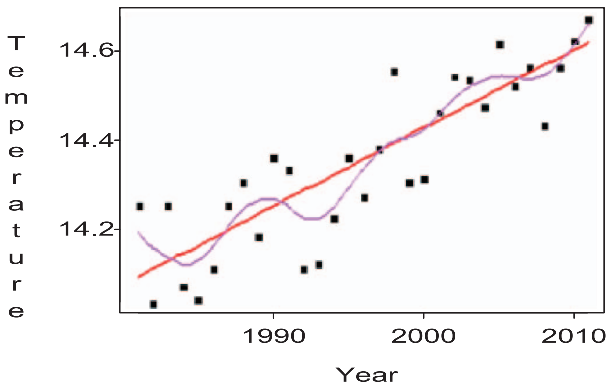
Table 3

Model	Degrees of freedom	Mean square error	R-square
Linear	29	0.0094	0.7372
Quadratic	28	0.0094	0.7450
Kernel	3.417	0.0095	0.7468
Loess	9.376	0.0077	0.8402
Spline	8.750	0.0080	0.8290

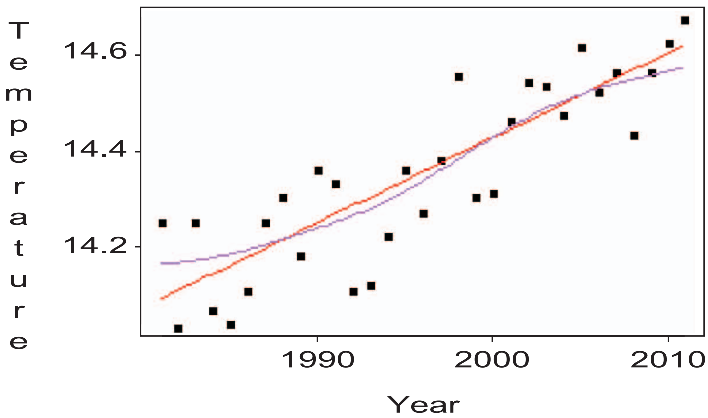
The graphs with regard to non-parametric and semi-parametric fits have been presented in the Annexure given below. Each graph exhibits (a) plots of temperature records (dots), (b) the fitted straight line (red line), and (c) the specific nonparametric/semi-parametric model fitted (in pink colour), mentioned in the heading with respect to each graph.

Annexure

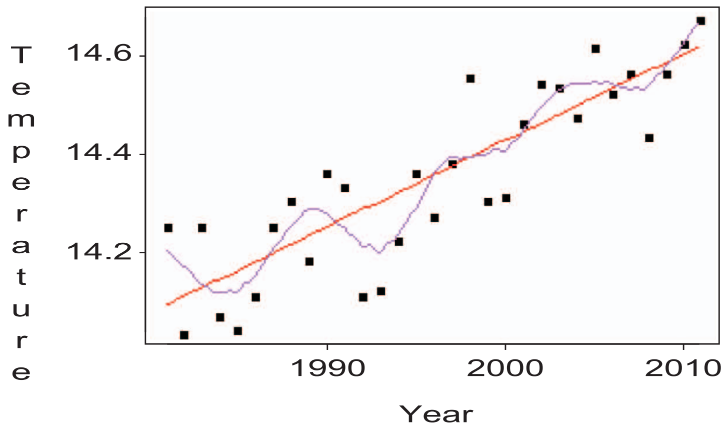
Spline Fit



Kernel Fit



Loess Fit



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