PREDICTION OF CLIMATE CHANGE USING ARIMA MODEL

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Abstract:

The climate and weather system prediction has always attracted interest. Climate change risks including physical risks, liability risks and transition risks, it's directly affecting the insurance industry. Climate change is majorly affecting the insurance sector; they are such as extreme heat during summer and extreme rainfall (Flood). It affects both insurance and reinsurance sector. Constructing the model is a necessary process but choosing the model which suits our data is very necessary. In those days the weather reports telecast in news but now even our smart phone notified the weather. In this paper study the climate prediction algorithms using R and also using Cost-free R language tool to forecast the climate using time ARIMA model for the Indian climate.

Key words: *Climate change, insurance, prediction, ARIMA Model*

Introduction:

Climate Change is real. What makes it worse is because of the human activities that are not environment friendly, in the example using fossil fuel for the vehicle, coal-powered generator, cement production, etc. One of the effects of these activities is increasing in temperature and depletion on the ozone layer. Before we build the model, we have to know the data first. How it looks, how different does the pattern they are. I will describe what the data set really is and what the information contains on it. The 2019–20 Australian bushfires killed more than a billion animals and caused more than \$4.4 billion in damage. Climate-linked issues, such as extreme heat, natural disasters, and biodiversity loss and the failure to respond to these challenges in time dominate reports issued by organizations such as the World Economic Forum.

At first glance, the effects of climate change may not seem detrimental to property and casualty (P&C) insurers. They can use the annual policy cycle and their sophisticated understanding of evolving risks to reprice and rearrange portfolios to avoid long-term exposure to climate events.

And the growth in the value at risk and possibly volatility should increase the demand for new and different insurance solutions and services, which, in turn, could expand the industry's opportunities. Insurers, however, must be careful not to underestimate the true threat of climate change. Because its effects are systemic, climate risk is likely to stress local economies and more grimly cause market failures that affect both consumers and insurers. More frequent catastrophic events, in combination with the need to meet evolving regulatory requirements, can threaten company business models and make insuring some risk unaffordable for customers or unfeasible for insurers.

Methodology:

In this paper the climate prediction did with Autoregressive Integrated Moving Average (ARIMA) model for time series data, is a forecasting algorithm based on the idea that the information in the past values of the time series can alone be used to predict the future values.

Data Analysis

Actuaries, statisticians and many other professionals are increasingly engaged in analyzing and interpreting large data sets, in order to determine whether there is any relationship between variables, and to assess the strength of that relationship. Exploratory data analysis (EDA) is the process of analyzing data to gain further insight into the nature of the data, its patterns and relationships between the variables, before any formal statistical techniques are applied. That is we approach the data free of any pre-conceived assumptions or hypotheses. We first see the patterns in the data before we impose any views on it and fit models.

Here we have 56 years of past data from 1961 to 2016 for temperature, rainfall, crop production and the area of land used by agriculture in INDIA. The dataset are shown below:

Year	Temperature	Rainfall	Area of land	Crop production
1961	24	116.61	17.4952	34.95
1962	24.04	99.82	17.6482	34.64
1963	24.15	101.75	17.6154	35.66
1964	24.1	103.69	17.6712	36.61
1965	24.07	78.94	17.7177	34.47
1966	24.36	88.18	17.753	34.15
1967	24.11	96.16	17.7807	36.78
1968	23.94	88.28	17.8364	38.59
1969	24.46	95.67	17.7792	39.94
1970	24.26	104.59	17.7817	42.44
1971	23.91	101.42	17.7946	43.02
1972	24.1	78.92	17.8751	40.6
1973	24.41	101.63	17.8751	44.16
1974	24	87.93	17.9282	42.24
1975	23.74	107.9	17.9694	47.05
1976	24.07	94.28	17.9649	46
1977	24.35	105.82	17.9591	50.24
1978	24.24	103.11	18.0592	52.4
1979	24.57	85.83	18.058	48.82
1980	24.55	98.53	18.0272	50.43
1981	24.27	97.54	18.0401	54.02
1982	24.15	90.38	18.0771	52.74
1983	24.12	110.07	18.0462	59.44
1984	24.26	96.73	18.1452	60.31
1985	24.45	95.41	18.134	61.21
1986	24.2	94.8	18.1192	61.16
1987	24.57	90.73	18.1543	59.85
1988	24.42	111.84	18.1091	67
1989	24.03	93.94	18.1501	71.58

Year	Temperature	Rainfall	Area of land	Crop production
1989	24.03	93.94	18.1501	71.58
1990	24.21	116.78	18.1413	72.59
1991	24.28	97.52	18.1586	73.68
1992	24.15	91.88	18.1305	77.07
1993	24.43	100.65	18.1382	79.74
1994	24.46	107.94	18.1291	82.07
1995	25.29	103.54	18.0945	83.68
1996	24.55	98.58	18.0589	87.07
1997	24.1	98.59	18.0981	88.84
1998	24.76	100.73	18.0874	90.18
1999	24.67	93.05	18.1021	94.32
2000	24.6	86.28	18.0975	92.08
2001	24.73	92.11	18.0487	94.78
2002	25	81.83	18.056	84.74
2003	24.72	103.63	18.0249	96.97
2004	24.74	90.04	18.0375	94.12
2005	24.58	100.68	18.0126	99.9
2006	25.06	96.81	17.9906	105.98
2007	24.77	98.28	17.962	116.23
2008	24.61	93.18	17.9757	117.28
2009	25.11	79.48	18.0068	112.83
2010	25.13	101.3	17.9573	124.91
2011	24.67	93.03	17.967	134.07
2012	24.69	87.89	17.9642	136.19
2013	24.82	103.55	17.9698	141.74
2014	24.73	83.61	17.9721	144.36
2015	24.91	87.52	17.9721	139.6
2016	26.45	88.03	17.9721	142.8

Relationship between the temperature, rainfall, crop production and area of land used by agriculture

First import the ggplot2 package in r and then import the required data for analysis. Then we can use the ggplot graph for our data. Insert our temperature, rainfall, crop production and area of land (in sq mtr lakhs) and we can use the different color for dataset. What we can conclude is the crop production (Yellow color) is continuous increasing and the rainfall data (Blue color) is stationary see in figure 2. The temperature (Red color) is increased in some period and decreased in some period and the area of land (Green color) is lower than 1980s' when compared to 1960s' but now the land used for agriculture is slowly decreased shown in figure 3.

Figure 2: Plots of temperature, rainfall, crop production, area of land

Figure 3: Plots of temperature and crop production

The Kendall rank correlation coefficient

Kendall's rank correlation coefficient τ measures the strength of dependence of rank correlation between two variables. Like the Spearman rank correlation coefficient, the Kendall rank correlation coefficient considers only the relative values of the bivariate data, and not their actual values. It is far more intensive from a calculation viewpoint, however, since it considers the relative values of all possible pairs of bivariate data, not simply the rank of X_i and Y_i for a given i . Let n_c be the number of concordant pairs, and let n_d be the number of discordant pairs. Assuming that there are no ties, the Kendall coefficient τ is defined as:

$$\tau = \frac{n_c - n_d}{n(n-1)}$$

Variables	Correlation value	Results
Year and Crop production	0.9697759	The year and crop production move together in the same direction but there is not a direct relationship.
Temperature and Crop production	0.7278388	The temperature and crop production move together in the same direction but there is not a direct relationship.
Rainfall and Crop production	0.0668009	The rainfall and crop production move together in the same direction but there is not a direct relationship.
Area of land and Crop production	0.3961773	The area of land and crop production move together in the same direction but there is not a direct relationship.

Table 1: Correlation table

The dependent variable is crop production and the independent variables are year, temperature, rainfall and the area of land.

Linear correlation between a pair of variables looks at the strength of the linear relationship between them. The diagram below shows the various degree of positive correlation:

Figure 4: Perfect positive correlation

Figure 5: Strong positive correlation

Figure 6: Weak positive correlation

For multivariate data sets with large dimensionality various techniques such as cluster analysis and principle components analysis (also called factor analysis) can be used to reduce the complexity of the data set.

Figure 7: Relationship plots of Year, Temperature, Rainfall, and Area of land and Crop production

Temperature Forecasting

Import the temperature dataset in RStudio to predict the future temperature of India for next 25 years. And check the class of data, if the dataset are not in time series change the data into time series. Import some packages like forecast and t series; it's useful for forecasting in R.

Minimum	23.74
1 st Quarter	24.14
Median	24.43
Mean	24.47
3 rd Quarter	24.70
Maximum	26.45

Plot the data in auto plot function (figure 8), we can check the data is stationary or non-stationary. If the data is non stationary convert the data into stationary and then proceed to next step. Our temperature data is non stationary we can find by using the Augmented Dickey-Fuller test shortly called as `adf.test`. Here we the p-value is 0.1225 is greater than 0.05 so, the data is non-stationary.

Figure 8: Graph of temperature

We can detect that the data is stationary or not using the ACF (Autocorrelation Function) and PACF (Partial Autocorrelation Function). If the graph is above and below the blue line, the data is non-stationary.

Figure 9: ACF of temperature

Figure 10: PACF of temperature

In above figure 9 and 10 we saw the ACF and PACF are above than blue lines. So differentiate the data and check the adf test and also the ACF and PACF. Now calculate the autocorrelation function and partial autocorrelation function of residuals, the lines are below the blue dotted line (figure 11 & 12).

Figure 11: ACF of temp residuals

Figure 12: PACF of temp residuals

Again we calculate the adf test to see the data is stationary or not. Here we have a p-value is 0.04584 so, the data is stationary. Plot the graph to see the result (figure 13). If the data is stationary means the mean and variance are constant throughout the period. And use the forecast in build function to predicting the future.

Figure 13: Plot of temperature (Stationary)

R Code:

```
temp_model = auto.arima(temp_ts, ic = "aic", trace = TRUE)
temp_model
acf(temp_model$residuals)
pacf(temp_model$residuals)
temp_forecast = forecast(temp_model, level = c(90), h = 25)
temp_forecast
```

We can use the auto Arima function to calculate the p, d and q. Suppose we manually calculate the p, d and q means the aic and bic values are higher when compared to auto Arima function. The Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) values are least value when compared to others. That means the p, d, q values are best fit to predicting the future. We use the 90 per cent level of significant to forecasting for next 25 years (figure 14). Here we take the p, d, q value is (2,1,1) and the AIC value is 34.1 and BIC value is 44.13.

Figure 14: Temperature forecasting

We conclude that the year is increases the temperature of India is also increases.

Rainfall Forecasting

Import the rainfall dataset in RStudio to predict the future rainfall of India for next 25 years. And check the class of data, if the dataset are not in time series change the data into time series.

Minimum	78.92
1 st Quarter	90.30
Median	96.77

Mean	96.38
3 rd Quarter	101.66
Maximum	116.78

Plot the data in graph format (figure 15), we can check the data is stationary or non-stationary. If the data is non stationary convert the data into stationary and then proceed to next step. Our rainfall data is stationary we can find by using the Augmented Dickey-Fuller test shortly called as `adf.test`. The p-value is 0.02231 lower than 0.05 means the data is stationary. If the data is stationary means the mean and variance are constant.

Figure 15: Graph of rainfall in India

R Code:

```
autoplot(rain_ts,xlab = "Year",ylab = "Rainfall",main = "Rainfall in INDIA")
acf(rain_ts)
pacf(rain_ts)
adf.test(rain_ts)
```

And then we calculate the autocorrelation function and partial autocorrelation function (figure 16 & 17) to cross check the data is stationary or not and also calculate the p, d, q value. But our rainfall data is stationary, so the d values are zero.

Figure 16: ACF of rainfall

Figure 17: PACF of rainfall

We can use the auto Arima function to calculate the p, d and q. Suppose we manually calculate the p, d and q means the aic and bic values are higher when compared to auto Arima function. The Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) values are least value when compared to others. That means the p, d, q values are best fit to predicting the

future. The AIC value is 407.69 is the best fit for forecasting when compared to others. We use the 90 per cent level of significant to forecasting for next 25 years (figure 18).

Figure 18: Rainfall Forecasting

R Code:

```
acf(rain_ts)
pacf(rain_ts)
adf.test(rain_ts)
rain_model = auto.arima(rain_ts,ic = "aic",trace = TRUE)
rain_model
acf(rain_model$residuals)
pacf(rain_model$residuals)
rain_forecast = forecast(rain_model,level = c(90),h = 25)
rain_forecast
autoplot(rain_forecast,xlab = "year",ylab = "Rainfall in mm",main = "Forecasting")
```

Crop Production Forecasting

Import the crop production dataset in RStudio to predict the future crop production of India for next 25 years. And check the class of data, if the dataset are not in time series change the data into time series. Import some packages like forecast and time series; it's useful for forecasting in R.

Minimum	34.15
1 st Quarter	45.54
Median	69.29
Mean	74.79
3 rd Quarter	94.44
Maximum	144.36

Plot the data in auto plot function (figure 19), we can check the data is stationary or non-stationary. If the data is non stationary convert the data into stationary and then proceed to next step. Our crop production data is non stationary we can find by using the Augmented Dickey-Fuller test shortly called as `adf.test`. The p-value is 0.8595 greater than 0.05 means the data is non-stationary.

Figure 19: Plot of Crop production index

We can detect that the data is stationary or not using the ACF (Autocorrelation Function) and PACF (Partial Autocorrelation Function). If the graphs are above and below the blue line, the data is non-stationary.

Figure 20: ACF of crop production

Figure 21: PACF of crop production

In above figure 20 and 21 we saw the ACF are above than blue lines and the PACF single line are above the blue line. So differentiate the data and check the adf test and also the ACF and PACF. Now calculate the autocorrelation function and partial autocorrelation function of residuals, the lines are below the blue dotted line (figure 22 & 23).

Figure 22: ACF of crop production residual

Figure 23: PACF of crop production residual

Again we calculate the adf.test, the p-value is 0.02294 is lower than 0.05 so the data is stationary. Plot the graph to see the result (figure 24). If the data is stationary means the mean and variance are constant throughout the period. And use the forecast in build function to predicting the future.

R Code:

```
acf(crop_ts)
pacf(crop_ts)
adf.test(crop_ts)
crop_df = diff(crop_ts)
adf.test(crop_df)
autoplot(crop_df,xlab = "Year",ylab = "Crop production",main = "Crop production in India")
```

Figure 24: Graph of crop production (Stationary)

We can use the auto Arima function to calculate the p, d and q. Suppose we manually calculate the p, d and q means the aic and bic values are higher when compared to auto Arima function. The Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) values are least value when compared to others. That means the p, d, q values are best fit to predicting the future. The p, d, q value is (1,1,0) is the best fit for forecasting and the AIC value is 310.61 and the BIC value is 316.63. We use the 90 per cent level of significant to forecasting for next 25 years from 2017 to 2041 (figure 25).

Figure 25: Crop Production Forecasting

We conclude that as the year increases, the crop production in India also gradually increases.

Area of land Forecasting

Import the area of land dataset in RStudio to predict the future area of land used by agriculture of India for next 25 years. And check the class of data, if the dataset are not in time series change the data into time series. Import some packages like forecast and time series; it's useful for forecasting in R.

Minimum	17.50
1 st Quarter	17.95

Median	18.01
Mean	17.98
3 rd Quarter	18.10
Maximum	18.16

Plot the data in auto plot function (figure 26), we can check the data is stationary or non-stationary. If the data is non stationary convert the data into stationary and then proceed to next step. The area of land used by agriculture data is non stationary we can find by using the Augmented Dickey-Fuller test shortly called as `adf.test`. The p-value is 0.5934 greater than 0.05 means the data is non-stationary.

Figure 26: Graph of area of land used by agricultural

We can detect that the data is stationary or not using the ACF (Autocorrelation Function) and PACF (Partial Autocorrelation Function). If the graph is above and below the blue line, the data is non-stationary.

Figure 27: ACF of area of land

Figure 28: PACF of area of land

In above figure 27 and 28 we saw the ACF and PACF are above than blue lines. So differentiate the data and check the `adf.test` and also the ACF and PACF. Now calculate the autocorrelation function and partial autocorrelation function of residuals, the lines are below the blue dotted line (figure 29 & 30).

Figure 29: ACF of area of land residual

Figure 30: PACF of area of land residual

Again we calculate the augmented dickey-fuller test the p-value is 0.02235 is lower than 0.05 so the data is stationary. Plot the graph to see the result (figure 31). If the data is stationary means the mean and variance are constant throughout the period. And use the forecast in build function to predicting the future.

R Code:

```
class(land_ts)
plot(land_ts)
autoplot(land_ts,xlab = "Year",ylab = "Land (sq in Lakh)",main = "Area of land")
acf(land_ts)
pacf(land_ts)
adf.test(land_ts)
land_df = diff(land_ts)
adf.test(land_df)
autoplot(land_df,xlab = "Year",ylab = "Land (sq in Lakh)",main = "Area of land")
land_model = auto.arima(land_ts,ic = "aic",trace = TRUE)
land_model
```

Figure 31: Graph of Area of land used by agricultural (Stationary)

We can use the auto arima function to calculate the p, d and q. Suppose we manually calculate the p, d and q means the aic and bic values are higher when compared to auto arima function. The Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) values are least value when compared to others. That means the p, d, q values are best fit to predicting the future. We use the 90 per cent level of significant to forecasting for next 25 years (figure 32). The (p,d,q) value is (2,2,2) and the AIC value is -195.83 and the BIC value is -185.89 is best fit for prediction.

Figure 32: Area of land used by agricultural Forecasting

We conclude that the year is increases and the area of land used by agricultural in India is also slightly increases.

Conclusion

Since the temperature ranges from 24.66 to 25.57 degrees Celsius, the rainfall ranges from 93.95 to 97.18 millimeters, and the field area ranges from 17.97 to 18.15 square meters in lakh, we may infer that crop production over the next twenty-five years would steadily rise from 144.5 to 191.7 indexes. Despite our predictions, we can see that while individual population declines and therefore agricultural land decreases, crop demand for the mass population increases. Farmers use hybrid variety plants, seeds, and other goods to improve crop yield when operating with a restricted amount of ground. However, it uses a lot of water, and since rainfall is falling in contrast to previous years, underground water levels are falling as well, causing the crop to fade.

We need to raise awareness among farmers about the characteristics and volume of water that should be used for hybrid variety seeds in order to minimize the chance of destroying them all. We also need to raise awareness about crop insurance. Many real estate brokers and multinational corporations are attempting to enter the Agri land market in India. The government can amend the act to secure divide Agri land from private businesses. (For example, the government should encourage farmers to do only Agri in agro - based property, and the government should not help any organizations that generate revenue for the country.) The GDP rate would rise if the government invests in agriculture.

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