CO2 Levels (2014-2024): Trends & Cycles

2024-11-18

```
include=FALSE
knitr::opts_chunk$set(echo = TRUE)
library(dplyr)
```

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
library(ggplot2)
library(car)
```

```
## Loading required package: carData
```

```
##
## Attaching package: 'car'
```

```
## The following object is masked from 'package:dplyr':
##
##     recode
```

```
co2_concentration <- read.csv("/cloud/project/co2 concentration.csv")
```

```
#Descriptive statistics
head(co2_concentration) #Shows the first 6 rows
```

```
##   year month day  cycle  trend
## 1 2014     1  25 397.95 396.59
## 2 2014     1  26 397.97 396.60
## 3 2014     1  27 397.99 396.61
## 4 2014     1  28 398.01 396.62
## 5 2014     1  29 398.03 396.62
## 6 2014     1  30 398.05 396.63
```

```
tail(co2_concentration) #shows the last  rows by default.
```

```
##      year month day  cycle  trend
## 3941 2024    11   8 423.81 424.00
## 3942 2024    11   9 423.86 424.01
## 3943 2024    11  10 423.91 424.02
## 3944 2024    11  11 423.96 424.03
## 3945 2024    11  12 424.00 424.04
## 3946 2024    11  13 424.05 424.04
```

```r
str(co2_concentration) #To understand the structure of the data frame
```

```
## 'data.frame':    3946 obs. of  5 variables:
##  $ year : int  2014 2014 2014 2014 2014 2014 2014 2014 2014 2014 ...
##  $ month: int  1 1 1 1 1 1 1 2 2 2 ...
##  $ day  : int  25 26 27 28 29 30 31 1 2 3 ...
##  $ cycle: num  398 398 398 398 398 ...
##  $ trend: num  397 397 397 397 397 ...
```

```r
summary(co2_concentration) #Provides summary of the data, it provides statistics like the minimum, maxi
```

```
##       year          month             day            cycle
##  Min.   :2014   Min.   : 1.000   Min.   : 1.00   Min.   :394.1
##  1st Qu.:2016   1st Qu.: 4.000   1st Qu.: 8.00   1st Qu.:403.5
##  Median :2019   Median : 7.000   Median :16.00   Median :410.0
##  Mean   :2019   Mean   : 6.494   Mean   :15.72   Mean   :410.0
##  3rd Qu.:2022   3rd Qu.: 9.000   3rd Qu.:23.00   3rd Qu.:416.4
##  Max.   :2024   Max.   :12.000   Max.   :31.00   Max.   :424.1
##      trend
##  Min.   :396.6
##  1st Qu.:403.9
##  Median :410.2
##  Mean   :410.0
##  3rd Qu.:416.6
##  Max.   :424.0
```

```r
co2_concentration$Season <- case_when(
  co2_concentration$month %in% c(12, 1, 2) ~ "Winter",
  co2_concentration$month %in% c(3, 4, 5) ~ "Spring",
  co2_concentration$month %in% c(6, 7, 8) ~ "Summer",
  co2_concentration$month %in% c(9, 10, 11) ~ "Autumn"
  )  # This bit will help us to analyze how CO  levels vary across seasons, and also help us to understa
```

```r
co2_concentration$Season <- factor(co2_concentration$Season, levels = c("Winter", "Spring", "Summer", "
#Convert the "Season" column into an ordered factor to ensure the seasons follow a logical order
# (Winter < Spring < Summer < Autumn). This is useful for analysis and visualization where
# the natural sequence of seasons matters, such as sorting or comparisons.
```

```r
str(co2_concentration$Season)
```

```
##  Ord.factor w/ 4 levels "Winter"<"Spring"<..: 1 1 1 1 1 1 1 1 1 1 ...
```

```r
#To check that the factor is indeed an ordered factor
```

```r
co2_concentration <- co2_concentration %>%
  group_by(year) %>%
  mutate(Annual_Change = trend - lag(trend))
#Annual rate change of year-over-year CO2_Concentration trend
```

```r
co2_concentration <- co2_concentration %>%
  mutate(Annual_Change_Percentage = (trend - lag(trend)) / lag(trend) * 100)
#This column is for the percentage change in CO2 concentration compared to the previous year. Its purpo
```

```r
#summary of the dataset
summary(co2_concentration)
```

```
##       year          month             day            cycle
```

```
##  Min.   :2014   Min.   : 1.000   Min.   : 1.00   Min.   :394.1
##  1st Qu.:2016   1st Qu.: 4.000   1st Qu.: 8.00   1st Qu.:403.5
##  Median :2019   Median : 7.000   Median :16.00   Median :410.0
##  Mean   :2019   Mean   : 6.494   Mean   :15.72   Mean   :410.0
##  3rd Qu.:2022   3rd Qu.: 9.000   3rd Qu.:23.00   3rd Qu.:416.4
##  Max.   :2024   Max.   :12.000   Max.   :31.00   Max.   :424.1
##
##      trend          Season     Annual_Change      Annual_Change_Percentage
##  Min.   :396.6   Winter: 938   Min.   :0.000000   Min.   :0.000000
##  1st Qu.:403.9   Spring:1012   1st Qu.:0.000000   1st Qu.:0.000000
##  Median :410.2   Summer:1012   Median :0.010000   Median :0.002402
##  Mean   :410.0   Autumn: 984   Mean   :0.006961   Mean   :0.001697
##  3rd Qu.:416.6                 3rd Qu.:0.010000   3rd Qu.:0.002460
##  Max.   :424.0                 Max.   :0.010000   Max.   :0.002521
##                                NA's   :11         NA's   :11
```

```
#Finding missing values in the Annual_Change Column and replace with the mean
co2_concentration$Annual_Change[is.na(co2_concentration$Annual_Change)] <- mean(co2_concentration$Annual
```

```
#Replace missing values in the Annual_Change_Percentage column and replace with the mean
co2_concentration$Annual_Change_Percentage[is.na(co2_concentration$Annual_Change_Percentage)] <- mean(co
```

```
#summary of the dataset
summary(co2_concentration)
```

```
##       year          month             day            cycle
##  Min.   :2014   Min.   : 1.000   Min.   : 1.00   Min.   :394.1
##  1st Qu.:2016   1st Qu.: 4.000   1st Qu.: 8.00   1st Qu.:403.5
##  Median :2019   Median : 7.000   Median :16.00   Median :410.0
##  Mean   :2019   Mean   : 6.494   Mean   :15.72   Mean   :410.0
##  3rd Qu.:2022   3rd Qu.: 9.000   3rd Qu.:23.00   3rd Qu.:416.4
##  Max.   :2024   Max.   :12.000   Max.   :31.00   Max.   :424.1
##      trend          Season     Annual_Change      Annual_Change_Percentage
##  Min.   :396.6   Winter: 938   Min.   :0.000000   Min.   :0.000000
##  1st Qu.:403.9   Spring:1012   1st Qu.:0.000000   1st Qu.:0.000000
##  Median :410.2   Summer:1012   Median :0.010000   Median :0.002402
##  Mean   :410.0   Autumn: 984   Mean   :0.006961   Mean   :0.001697
##  3rd Qu.:416.6                 3rd Qu.:0.010000   3rd Qu.:0.002460
##  Max.   :424.0                 Max.   :0.010000   Max.   :0.002521
```

```
# Z-Score for Co2_Concentration trend
co2_concentration <- co2_concentration %>%
  mutate(
    z_score_trend = (trend - mean(trend, na.rm = TRUE)) / sd(trend, na.rm = TRUE),
    anomaly = ifelse(abs(z_score_trend) > 1.5, TRUE, FALSE)
  )

# View rows with anomalies
anomalies <- co2_concentration %>% filter(anomaly == TRUE)
print(anomalies)
```

```
## # A tibble: 502 x 10
## # Groups:   year [11]
##     year month   day cycle trend Season Annual_Change Annual_Change_Percentage
##    <int> <int> <int> <dbl> <dbl> <ord>          <dbl>                     <dbl>
##  1  2014     1    25  398.  397. Winter       0.00696                   0.00170
```

```
##  2  2014     1    26  398.  397. Winter       0.0100                  0.00252
##  3  2014     1    27  398.  397. Winter       0.0100                  0.00252
##  4  2014     1    28  398.  397. Winter       0.0100                  0.00252
##  5  2014     1    29  398.  397. Winter       0                       0
##  6  2014     1    30  398.  397. Winter       0.0100                  0.00252
##  7  2014     1    31  398.  397. Winter       0.0100                  0.00252
##  8  2014     2     1  398.  397. Winter       0.0100                  0.00252
##  9  2014     2     2  398.  397. Winter       0                       0
## 10  2014     2     3  398.  397. Winter       0.0100                  0.00252
## # i 492 more rows
## # i 2 more variables: z_score_trend <dbl>, anomaly <lgl>
```

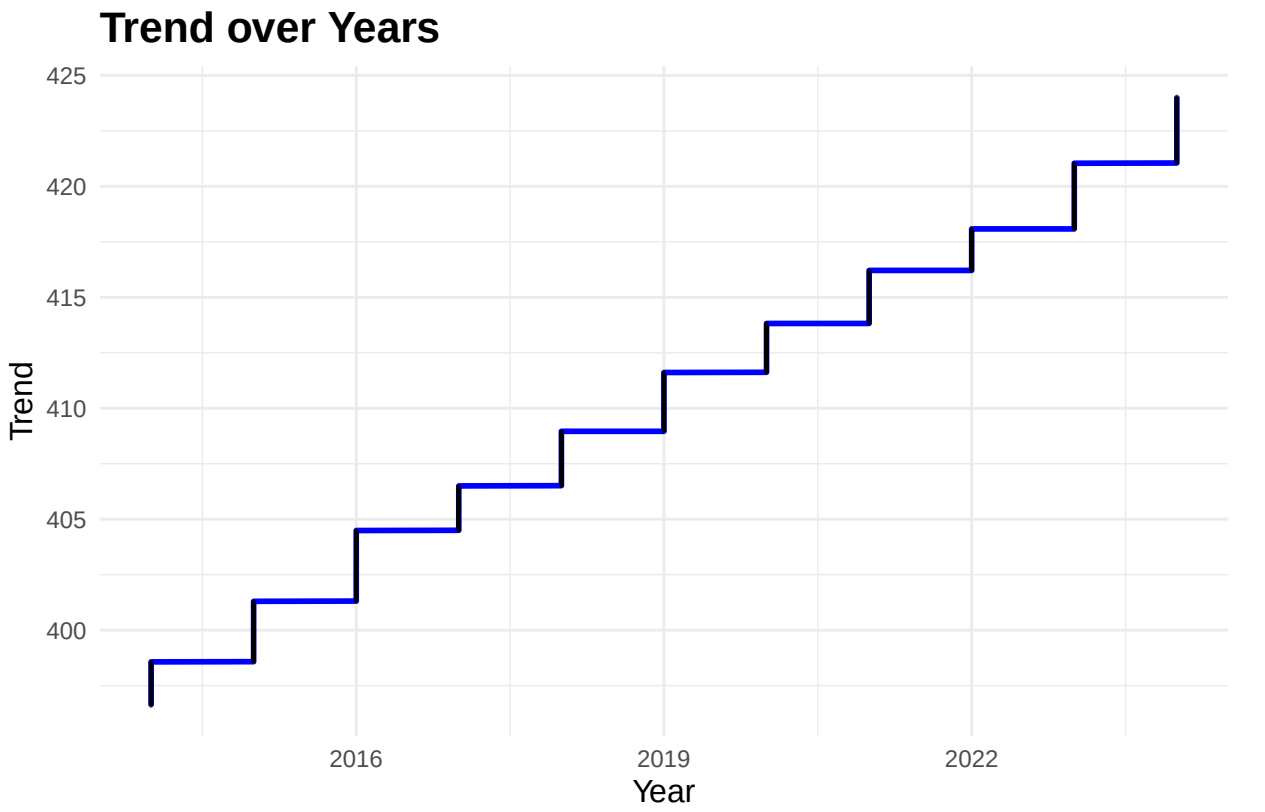
```r
# Z-Score for Co2_Concentration trend
co2_concentration <- co2_concentration %>%
  mutate(
    z_score_cycle = (cycle - mean(cycle, na.rm = TRUE)) / sd(cycle, na.rm = TRUE),
    anomaly = ifelse(abs(z_score_cycle) > 1.5, TRUE, FALSE)  # Corrected column name here
  )
```

```r
#Summary of dataset after creating columns
summary(co2_concentration)
```

```
##       year          month             day            cycle
##  Min.   :2014   Min.   : 1.000   Min.   : 1.00   Min.   :394.1
##  1st Qu.:2016   1st Qu.: 4.000   1st Qu.: 8.00   1st Qu.:403.5
##  Median :2019   Median : 7.000   Median :16.00   Median :410.0
##  Mean   :2019   Mean   : 6.494   Mean   :15.72   Mean   :410.0
##  3rd Qu.:2022   3rd Qu.: 9.000   3rd Qu.:23.00   3rd Qu.:416.4
##  Max.   :2024   Max.   :12.000   Max.   :31.00   Max.   :424.1
##      trend          Season     Annual_Change      Annual_Change_Percentage
##  Min.   :396.6   Winter: 938   Min.   :0.000000   Min.   :0.000000
##  1st Qu.:403.9   Spring:1012   1st Qu.:0.000000   1st Qu.:0.000000
##  Median :410.2   Summer:1012   Median :0.010000   Median :0.002402
##  Mean   :410.0   Autumn: 984   Mean   :0.006961   Mean   :0.001697
##  3rd Qu.:416.6                 3rd Qu.:0.010000   3rd Qu.:0.002460
##  Max.   :424.0                 Max.   :0.010000   Max.   :0.002521
##  z_score_trend         anomaly        z_score_cycle
##  Min.   :-1.8931076   Mode :logical   Min.   :-2.0970
##  1st Qu.:-0.8630888   FALSE:3355      1st Qu.:-0.7681
##  Median : 0.0007528   TRUE :591       Median : 0.3564
##  Mean   : 0.0000000                   Mean   : 0.0000
##  3rd Qu.: 0.8615464                   3rd Qu.: 0.7970
##  Max.   : 1.9243586                   Max.   : 1.6016
```

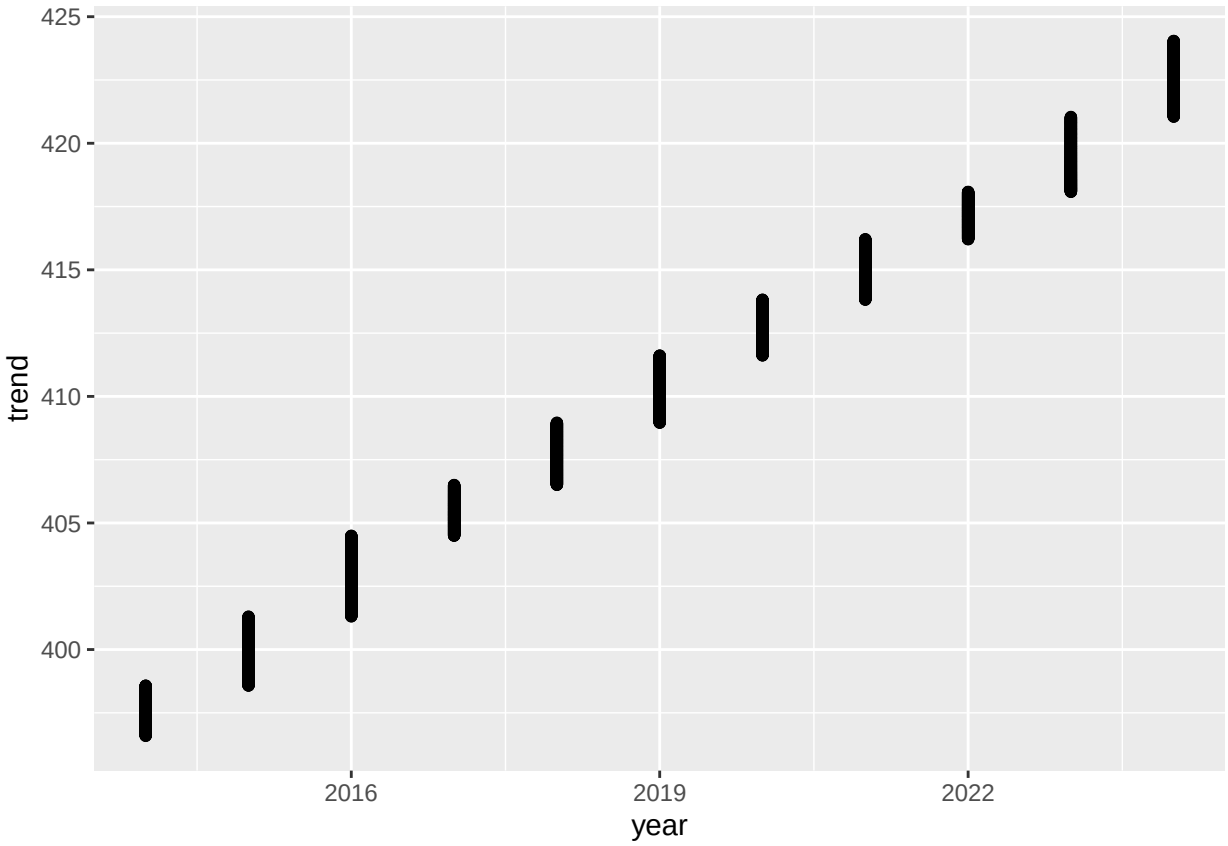
```r
#Visualizations

#Create a lineplot of Co2_Concentration vs time
ggplot(co2_concentration, aes(x=year,y=trend)) + geom_line(color = "blue", linewidth= 1) +
geom_point(size = 0.1, alpha = 0.2) +
labs(
title = "Trend over Years",
x = "Year",
y = "Trend",
caption = "Source: CO2 Concentration Dataset"
) +
theme_minimal() +
```

```
theme(
plot.title = element_text(size = 16, face= "bold"),
axis.title = element_text(size = 12),
legend.position = "bottom"
)
```

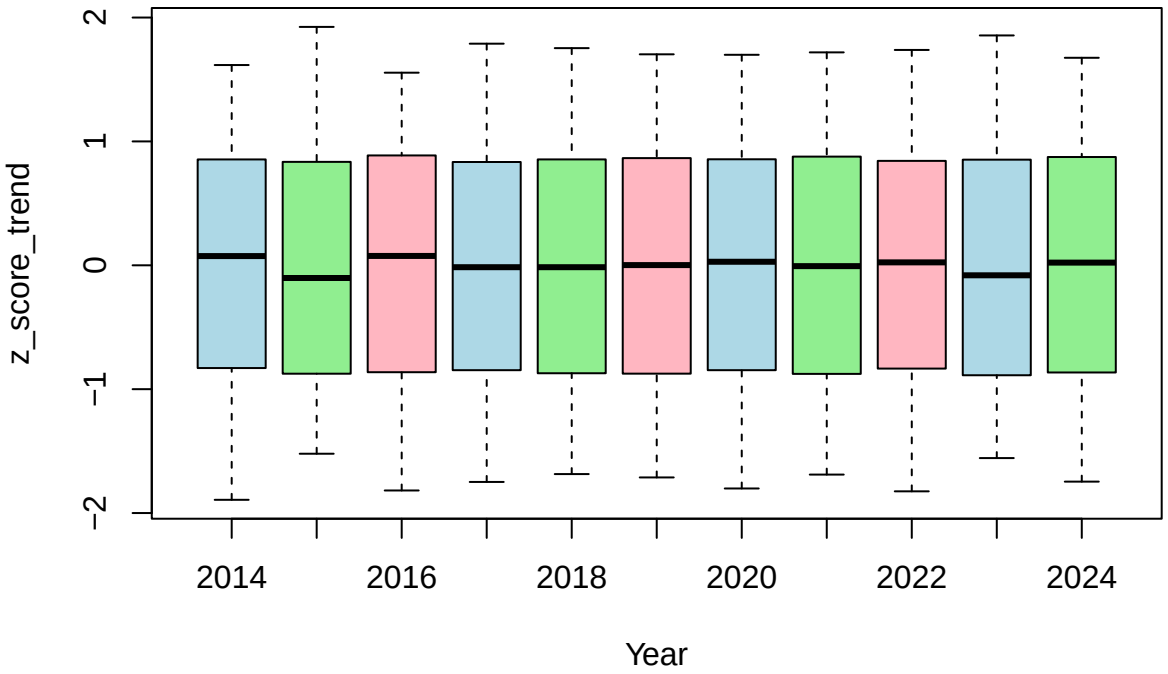


Source: CO2 Concentration Dataset

```
#Create a Scatterplot of Trend VS Year
ggplot(co2_concentration, aes(x = year, y = trend)) +  geom_point()
```




```
#Create a of boxplot of Z_Score
boxplot(z_score_trend ~ year, data = co2_concentration, xlab =
"Year", ylab = "z_score_trend", col = c("lightblue", "lightgreen","lightpink"))
```



```
"z_score_trend"
```

```
## [1] "z_score_trend"
```

```
str(co2_concentration)
```

```
## gropd_df [3,946 x 11] (S3: grouped_df/tbl_df/tbl/data.frame)
##  $ year                    : int [1:3946] 2014 2014 2014 2014 2014 2014 2014 2014 2014 2014 ...
##  $ month                   : int [1:3946] 1 1 1 1 1 1 1 2 2 2 ...
##  $ day                     : int [1:3946] 25 26 27 28 29 30 31 1 2 3 ...
##  $ cycle                   : num [1:3946] 398 398 398 398 398 ...
##  $ trend                   : num [1:3946] 397 397 397 397 397 ...
##  $ Season                  : Ord.factor w/ 4 levels "Winter"<"Spring"<..: 1 1 1 1 1 1 1 1 1 1 ...
##  $ Annual_Change           : num [1:3946] 0.00696 0.01 0.01 0.01 0 ...
##  $ Annual_Change_Percentage: num [1:3946] 0.0017 0.00252 0.00252 0.00252 0 ...
##  $ z_score_trend           : num [1:3946] -1.89 -1.88 -1.86 -1.84 -1.84 ...
##  $ anomaly                 : logi [1:3946] FALSE FALSE FALSE FALSE FALSE FALSE ...
##  $ z_score_cycle           : num [1:3946] 0.224 0.235 0.246 0.257 0.268 ...
##  - attr(*, "groups")= tibble [11 x 2] (S3: tbl_df/tbl/data.frame)
##   ..$ year : int [1:11] 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 ...
##   ..$ .rows: list<int> [1:11]
##   .. ..$ : int [1:341] 1 2 3 4 5 6 7 8 9 10 ...
##   .. ..$ : int [1:365] 342 343 344 345 346 347 348 349 350 351 ...
##   .. ..$ : int [1:366] 707 708 709 710 711 712 713 714 715 716 ...
##   .. ..$ : int [1:365] 1073 1074 1075 1076 1077 1078 1079 1080 1081 1082 ...
##   .. ..$ : int [1:365] 1438 1439 1440 1441 1442 1443 1444 1445 1446 1447 ...
##   .. ..$ : int [1:365] 1803 1804 1805 1806 1807 1808 1809 1810 1811 1812 ...
##   .. ..$ : int [1:366] 2168 2169 2170 2171 2172 2173 2174 2175 2176 2177 ...
##   .. ..$ : int [1:365] 2534 2535 2536 2537 2538 2539 2540 2541 2542 2543 ...
##   .. ..$ : int [1:365] 2899 2900 2901 2902 2903 2904 2905 2906 2907 2908 ...
##   .. ..$ : int [1:365] 3264 3265 3266 3267 3268 3269 3270 3271 3272 3273 ...
##   .. ..$ : int [1:318] 3629 3630 3631 3632 3633 3634 3635 3636 3637 3638 ...
##   .. ..@ ptype: int(0)
##   ..- attr(*, ".drop")= logi TRUE
```

```
#Check for correlation between trend, year and cycle. We checked correlation between the response varia

cor(co2_concentration[, c("trend", "year", "cycle")])
```

```
##           trend      year     cycle
## trend 1.0000000 0.9947421 0.9652067
## year  0.9947421 1.0000000 0.9742207
## cycle 0.9652067 0.9742207 1.0000000
```

```
#Linear Regression Model

# Build a linear regression model
model <- lm(trend ~ year + Season + month, data = co2_concentration)
```

```
summary(model)
```

```
##
## Call:
## lm(formula = trend ~ year + Season + month, data = co2_concentration)
##
## Residuals:
```

```
##      Min       1Q   Median       3Q      Max
## -0.74865 -0.24818  0.05041  0.23163  0.80964
##
## Coefficients:
##               Estimate Std. Error   t value Pr(>|t|)
## (Intercept) -4.558e+03  3.534e+00 -1289.824   <2e-16 ***
## year         2.460e+00  1.750e-03  1405.784   <2e-16 ***
## Season.L     3.551e-02  1.406e-02     2.525   0.0116 *
## Season.Q     3.590e-03  1.171e-02     0.307   0.7591
## Season.C    -6.928e-03  1.096e-02    -0.632   0.5275
## month        2.048e-01  2.166e-03    94.545   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 0.3423 on 3940 degrees of freedom
## Multiple R-squared:  0.998,  Adjusted R-squared:  0.998
## F-statistic: 3.965e+05 on 5 and 3940 DF,  p-value: < 2.2e-16
```

```
vif(model)  #To check the multicollinearity of between the predictor variables and if vif is > 5 or 10,
```

```
##            GVIF Df GVIF^(1/(2*Df))
## year   1.003009  1        1.001503
## Season 1.829010  3        1.105866
## month  1.832574  1        1.353726
```

```
#Evaluating our model's performance using R-squared,Mse,Mae
#Calculate the residuals to find mse (mean squared error)
predictions <- predict(model, co2_concentration)
residuals <- co2_concentration$trend - predictions
mse <- mean(residuals^2)
print(mse)
```

```
## [1] 0.1169993
```

```
#Calculate the mean absolute error (mae)
mae <- mean(abs(residuals))
print(mae)
```

```
## [1] 0.2777212
```

```
summary(model)$r.squared
```

```
## [1] 0.9980167
```

```
print(predictions)
```

```
##        1        2        3        4        5        6        7        8
## 396.6332 396.6332 396.6332 396.6332 396.6332 396.6332 396.6332 396.8380
##        9       10       11       12       13       14       15       16
## 396.8380 396.8380 396.8380 396.8380 396.8380 396.8380 396.8380 396.8380
##       17       18       19       20       21       22       23       24
## 396.8380 396.8380 396.8380 396.8380 396.8380 396.8380 396.8380 396.8380
##       25       26       27       28       29       30       31       32
## 396.8380 396.8380 396.8380 396.8380 396.8380 396.8380 396.8380 396.8380
##       33       34       35       36       37       38       39       40
## 396.8380 396.8380 396.8380 397.0488 397.0488 397.0488 397.0488 397.0488
##       41       42       43       44       45       46       47       48
## 397.0488 397.0488 397.0488 397.0488 397.0488 397.0488 397.0488 397.0488
```

```
##       49       50       51       52       53       54       55       56
## 397.0488 397.0488 397.0488 397.0488 397.0488 397.0488 397.0488 397.0488
##       57       58       59       60       61       62       63       64
## 397.0488 397.0488 397.0488 397.0488 397.0488 397.0488 397.0488 397.0488
##       65       66       67       68       69       70       71       72
## 397.0488 397.0488 397.2536 397.2536 397.2536 397.2536 397.2536 397.2536
##       73       74       75       76       77       78       79       80
## 397.2536 397.2536 397.2536 397.2536 397.2536 397.2536 397.2536 397.2536
##       81       82       83       84       85       86       87       88
## 397.2536 397.2536 397.2536 397.2536 397.2536 397.2536 397.2536 397.2536
##       89       90       91       92       93       94       95       96
## 397.2536 397.2536 397.2536 397.2536 397.2536 397.2536 397.2536 397.2536
##       97       98       99      100      101      102      103      104
## 397.4583 397.4583 397.4583 397.4583 397.4583 397.4583 397.4583 397.4583
##      105      106      107      108      109      110      111      112
## 397.4583 397.4583 397.4583 397.4583 397.4583 397.4583 397.4583 397.4583
##      113      114      115      116      117      118      119      120
## 397.4583 397.4583 397.4583 397.4583 397.4583 397.4583 397.4583 397.4583
##      121      122      123      124      125      126      127      128
## 397.4583 397.4583 397.4583 397.4583 397.4583 397.4583 397.4583 397.6882
##      129      130      131      132      133      134      135      136
## 397.6882 397.6882 397.6882 397.6882 397.6882 397.6882 397.6882 397.6882
##      137      138      139      140      141      142      143      144
## 397.6882 397.6882 397.6882 397.6882 397.6882 397.6882 397.6882 397.6882
##      145      146      147      148      149      150      151      152
## 397.6882 397.6882 397.6882 397.6882 397.6882 397.6882 397.6882 397.6882
##      153      154      155      156      157      158      159      160
## 397.6882 397.6882 397.6882 397.6882 397.6882 397.8930 397.8930 397.8930
##      161      162      163      164      165      166      167      168
## 397.8930 397.8930 397.8930 397.8930 397.8930 397.8930 397.8930 397.8930
##      169      170      171      172      173      174      175      176
## 397.8930 397.8930 397.8930 397.8930 397.8930 397.8930 397.8930 397.8930
##      177      178      179      180      181      182      183      184
## 397.8930 397.8930 397.8930 397.8930 397.8930 397.8930 397.8930 397.8930
##      185      186      187      188      189      190      191      192
## 397.8930 397.8930 397.8930 397.8930 398.0978 398.0978 398.0978 398.0978
##      193      194      195      196      197      198      199      200
## 398.0978 398.0978 398.0978 398.0978 398.0978 398.0978 398.0978 398.0978
##      201      202      203      204      205      206      207      208
## 398.0978 398.0978 398.0978 398.0978 398.0978 398.0978 398.0978 398.0978
##      209      210      211      212      213      214      215      216
## 398.0978 398.0978 398.0978 398.0978 398.0978 398.0978 398.0978 398.0978
##      217      218      219      220      221      222      223      224
## 398.0978 398.0978 398.0978 398.3158 398.3158 398.3158 398.3158 398.3158
##      225      226      227      228      229      230      231      232
## 398.3158 398.3158 398.3158 398.3158 398.3158 398.3158 398.3158 398.3158
##      233      234      235      236      237      238      239      240
## 398.3158 398.3158 398.3158 398.3158 398.3158 398.3158 398.3158 398.3158
##      241      242      243      244      245      246      247      248
## 398.3158 398.3158 398.3158 398.3158 398.3158 398.3158 398.3158 398.3158
##      249      250      251      252      253      254      255      256
## 398.3158 398.5205 398.5205 398.5205 398.5205 398.5205 398.5205 398.5205
##      257      258      259      260      261      262      263      264
## 398.5205 398.5205 398.5205 398.5205 398.5205 398.5205 398.5205 398.5205
```

```
##      265      266      267      268      269      270      271      272
## 398.5205 398.5205 398.5205 398.5205 398.5205 398.5205 398.5205 398.5205
##      273      274      275      276      277      278      279      280
## 398.5205 398.5205 398.5205 398.5205 398.5205 398.5205 398.5205 398.5205
##      281      282      283      284      285      286      287      288
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##      289      290      291      292      293      294      295      296
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##      305      306      307      308      309      310      311      312
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##      321      322      323      324      325      326      327      328
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##      329      330      331      332      333      334      335      336
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##      337      338      339      340      341      342      343      344
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##      345      346      347      348      349      350      351      352
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##      369      370      371      372      373      374      375      376
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##      385      386      387      388      389      390      391      392
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##      393      394      395      396      397      398      399      400
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##      401      402      403      404      405      406      407      408
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##      409      410      411      412      413      414      415      416
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##      417      418      419      420      421      422      423      424
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##      425      426      427      428      429      430      431      432
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##      433      434      435      436      437      438      439      440
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##      441      442      443      444      445      446      447      448
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##      449      450      451      452      453      454      455      456
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##      457      458      459      460      461      462      463      464
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##      465      466      467      468      469      470      471      472
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##      473      474      475      476      477      478      479      480
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##      481      482      483      484      485      486      487      488
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##      529      530      531      532      533      534      535      536
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##      537      538      539      540      541      542      543      544
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##      609      610      611      612      613      614      615      616
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##      617      618      619      620      621      622      623      624
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##      625      626      627      628      629      630      631      632
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##      633      634      635      636      637      638      639      640
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##      641      642      643      644      645      646      647      648
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##      649      650      651      652      653      654      655      656
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##      657      658      659      660      661      662      663      664
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##      665      666      667      668      669      670      671      672
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##      673      674      675      676      677      678      679      680
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##      681      682      683      684      685      686      687      688
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##      689      690      691      692      693      694      695      696
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##      697      698      699      700      701      702      703      704
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##      705      706      707      708      709      710      711      712
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##      721      722      723      724      725      726      727      728
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##      745      746      747      748      749      750      751      752
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##      793      794      795      796      797      798      799      800
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##      801      802      803      804      805      806      807      808
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##      809      810      811      812      813      814      815      816
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##      817      818      819      820      821      822      823      824
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##      825      826      827      828      829      830      831      832
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##      905      906      907      908      909      910      911      912
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##      929      930      931      932      933      934      935      936
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##      937      938      939      940      941      942      943      944
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##      945      946      947      948      949      950      951      952
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##      953      954      955      956      957      958      959      960
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##      969      970      971      972      973      974      975      976
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##      977      978      979      980      981      982      983      984
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##      985      986      987      988      989      990      991      992
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##      993      994      995      996      997      998      999     1000
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##     1001     1002     1003     1004     1005     1006     1007     1008
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##     1009     1010     1011     1012     1013     1014     1015     1016
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##     1017     1018     1019     1020     1021     1022     1023     1024
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##     1025     1026     1027     1028     1029     1030     1031     1032
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##     1033     1034     1035     1036     1037     1038     1039     1040
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##     1049     1050     1051     1052     1053     1054     1055     1056
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##     1057     1058     1059     1060     1061     1062     1063     1064
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##     1073     1074     1075     1076     1077     1078     1079     1080
## 404.0132 404.0132 404.0132 404.0132 404.0132 404.0132 404.0132 404.0132
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##     1097     1098     1099     1100     1101     1102     1103     1104
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##     1105     1106     1107     1108     1109     1110     1111     1112
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##     1113     1114     1115     1116     1117     1118     1119     1120
## 404.2179 404.2179 404.2179 404.2179 404.2179 404.2179 404.2179 404.2179
##     1121     1122     1123     1124     1125     1126     1127     1128
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##     1129     1130     1131     1132     1133     1134     1135     1136
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##     1145     1146     1147     1148     1149     1150     1151     1152
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##     1161     1162     1163     1164     1165     1166     1167     1168
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##     1169     1170     1171     1172     1173     1174     1175     1176
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##     1177     1178     1179     1180     1181     1182     1183     1184
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##     1185     1186     1187     1188     1189     1190     1191     1192
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##     1193     1194     1195     1196     1197     1198     1199     1200
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##     1201     1202     1203     1204     1205     1206     1207     1208
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##     1209     1210     1211     1212     1213     1214     1215     1216
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##     1217     1218     1219     1220     1221     1222     1223     1224
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##     1233     1234     1235     1236     1237     1238     1239     1240
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##     1249     1250     1251     1252     1253     1254     1255     1256
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##     1257     1258     1259     1260     1261     1262     1263     1264
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## 405.2729 405.2729 405.2729 405.2729 405.2729 405.2729 405.2729 405.2729
##     1281     1282     1283     1284     1285     1286     1287     1288
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##     1289     1290     1291     1292     1293     1294     1295     1296
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##     1297     1298     1299     1300     1301     1302     1303     1304
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##     1305     1306     1307     1308     1309     1310     1311     1312
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##     1313     1314     1315     1316     1317     1318     1319     1320
## 405.4777 405.4777 405.4777 405.6957 405.6957 405.6957 405.6957 405.6957
##     1321     1322     1323     1324     1325     1326     1327     1328
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##     1329     1330     1331     1332     1333     1334     1335     1336
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##     1337     1338     1339     1340     1341     1342     1343     1344
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##     1345     1346     1347     1348     1349     1350     1351     1352
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##     1353     1354     1355     1356     1357     1358     1359     1360
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##     1361     1362     1363     1364     1365     1366     1367     1368
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##     1369     1370     1371     1372     1373     1374     1375     1376
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##     1377     1378     1379     1380     1381     1382     1383     1384
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##     1385     1386     1387     1388     1389     1390     1391     1392
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##     1393     1394     1395     1396     1397     1398     1399     1400
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##     1401     1402     1403     1404     1405     1406     1407     1408
## 406.1052 406.1052 406.1052 406.1052 406.1052 406.1052 406.2655 406.2655
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##     1425     1426     1427     1428     1429     1430     1431     1432
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##     1497     1498     1499     1500     1501     1502     1503     1504
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## 408.5652 408.5652 408.5652 408.5652 408.5652 408.5652 408.5652 408.5652
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## 410.8204 410.8204 410.8204 410.8204 410.8204 410.8204 410.8204 410.8204
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## 410.8204 410.8204 411.0252 411.0252 411.0252 411.0252 411.0252 411.0252
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## 411.3931 411.3931 411.3931 411.3931 411.3931 411.3931 411.3931 411.3931
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## 411.3931 411.3931 411.3931 411.3931 411.3931 411.3931 411.3931 411.3931
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## 411.8087 411.8087 411.8087 411.8087 411.8087 411.8087 411.8087 411.8087
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## 411.8087 411.8087 411.8087 411.8087 411.8087 411.8087 411.8087 411.8087
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## 411.8087 411.8087 411.8087 411.8087 411.8087 411.8087 411.8087 411.8087
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## 412.6529 412.6529 412.6529 412.6529 412.6529 412.6529 412.6529 412.6529
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## 412.6529 412.6529 412.6529 412.6529 412.6529 412.6529 412.6529 412.6529
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## 412.8576 412.8576 412.8576 412.8576 412.8576 412.8576 412.8576 412.8576
##     2393     2394     2395     2396     2397     2398     2399     2400
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##     2401     2402     2403     2404     2405     2406     2407     2408
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##     2409     2410     2411     2412     2413     2414     2415     2416
## 412.8576 412.8576 412.8576 413.0757 413.0757 413.0757 413.0757 413.0757
##     2417     2418     2419     2420     2421     2422     2423     2424
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## 413.2804 413.2804 413.2804 413.2804 413.2804 413.2804 413.2804 413.2804
##     2465     2466     2467     2468     2469     2470     2471     2472
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##     2473     2474     2475     2476     2477     2478     2479     2480
## 413.4852 413.4852 413.4852 413.4852 413.4852 413.4852 413.4852 413.4852
##     2481     2482     2483     2484     2485     2486     2487     2488
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##     2489     2490     2491     2492     2493     2494     2495     2496
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##     2497     2498     2499     2500     2501     2502     2503     2504
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##     2513     2514     2515     2516     2517     2518     2519     2520
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##     2521     2522     2523     2524     2525     2526     2527     2528
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##     2529     2530     2531     2532     2533     2534     2535     2536
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##     2537     2538     2539     2540     2541     2542     2543     2544
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##     2545     2546     2547     2548     2549     2550     2551     2552
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##     2553     2554     2555     2556     2557     2558     2559     2560
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##     2561     2562     2563     2564     2565     2566     2567     2568
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##     2601     2602     2603     2604     2605     2606     2607     2608
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##     2609     2610     2611     2612     2613     2614     2615     2616
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##     2617     2618     2619     2620     2621     2622     2623     2624
## 414.2687 414.2687 414.2687 414.2687 414.2687 414.2687 414.2687 414.4734
##     2625     2626     2627     2628     2629     2630     2631     2632
## 414.4734 414.4734 414.4734 414.4734 414.4734 414.4734 414.4734 414.4734
##     2633     2634     2635     2636     2637     2638     2639     2640
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##     2641     2642     2643     2644     2645     2646     2647     2648
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## 414.4734 414.4734 414.4734 414.4734 414.4734 414.6782 414.6782 414.6782
##     2657     2658     2659     2660     2661     2662     2663     2664
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##     2665     2666     2667     2668     2669     2670     2671     2672
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##     2673     2674     2675     2676     2677     2678     2679     2680
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##     2681     2682     2683     2684     2685     2686     2687     2688
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##     2713     2714     2715     2716     2717     2718     2719     2720
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##     2721     2722     2723     2724     2725     2726     2727     2728
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##     2729     2730     2731     2732     2733     2734     2735     2736
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##     2737     2738     2739     2740     2741     2742     2743     2744
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##     2745     2746     2747     2748     2749     2750     2751     2752
## 415.1129 415.3176 415.3176 415.3176 415.3176 415.3176 415.3176 415.3176
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##     2761     2762     2763     2764     2765     2766     2767     2768
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##     2769     2770     2771     2772     2773     2774     2775     2776
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##     2777     2778     2779     2780     2781     2782     2783     2784
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##     2849     2850     2851     2852     2853     2854     2855     2856
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## 416.1054 416.1054 416.3131 416.3131 416.3131 416.3131 416.3131 416.3131
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## 417.1382 417.1382 417.1382 417.1382 417.1382 417.1382 417.1382 417.1382
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##     3049     3050     3051     3052     3053     3054     3055     3056
## 417.1382 417.3681 417.3681 417.3681 417.3681 417.3681 417.3681 417.3681
##     3057     3058     3059     3060     3061     3062     3063     3064
## 417.3681 417.3681 417.3681 417.3681 417.3681 417.3681 417.3681 417.3681
##     3065     3066     3067     3068     3069     3070     3071     3072
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## 417.5729 417.5729 417.5729 417.5729 417.5729 417.5729 417.5729 417.5729
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## 417.7776 417.7776 417.7776 417.7776 417.7776 417.7776 417.7776 417.7776
##     3137     3138     3139     3140     3141     3142     3143     3144
## 417.7776 417.7776 417.7776 417.7776 417.7776 417.9956 417.9956 417.9956
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## 417.9956 417.9956 417.9956 417.9956 417.9956 417.9956 417.9956 417.9956
##     3153     3154     3155     3156     3157     3158     3159     3160
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##     3161     3162     3163     3164     3165     3166     3167     3168
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##     3169     3170     3171     3172     3173     3174     3175     3176
## 417.9956 417.9956 417.9956 418.2004 418.2004 418.2004 418.2004 418.2004
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## 418.2004 418.2004 418.2004 418.2004 418.2004 418.2004 418.2004 418.2004
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## 418.2004 418.2004 418.2004 418.2004 418.2004 418.2004 418.2004 418.2004
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## 418.5654 418.5654 418.5654 418.5654 418.5654 418.5654 418.5654 418.5654
##     3241     3242     3243     3244     3245     3246     3247     3248
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## 418.5654 418.5654 418.5654 418.5654 418.5654 418.5654 418.5654 418.7731
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## 418.7731 418.7731 418.7731 418.7731 418.7731 418.7731 418.7731 418.7731
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## 418.7731 418.7731 418.7731 418.7731 418.7731 418.7731 418.7731 418.7731
##     3281     3282     3283     3284     3285     3286     3287     3288
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## 418.7731 418.7731 418.7731 418.7731 418.7731 418.7731 418.9778 418.9778
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## 418.9778 418.9778 418.9778 418.9778 418.9778 418.9778 418.9778 418.9778
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##     3321     3322     3323     3324     3325     3326     3327     3328
## 418.9778 418.9778 419.1887 419.1887 419.1887 419.1887 419.1887 419.1887
##     3329     3330     3331     3332     3333     3334     3335     3336
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##     3337     3338     3339     3340     3341     3342     3343     3344
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##     3345     3346     3347     3348     3349     3350     3351     3352
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## 419.1887 419.3934 419.3934 419.3934 419.3934 419.3934 419.3934 419.3934
##     3361     3362     3363     3364     3365     3366     3367     3368
## 419.3934 419.3934 419.3934 419.3934 419.3934 419.3934 419.3934 419.3934
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## 419.3934 419.3934 419.3934 419.3934 419.3934 419.3934 419.3934 419.3934
##     3377     3378     3379     3380     3381     3382     3383     3384
## 419.3934 419.3934 419.3934 419.3934 419.3934 419.3934 419.3934 419.5982
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## 419.5982 419.5982 419.5982 419.5982 419.5982 419.5982 419.5982 419.5982
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## 419.8281 419.8281 419.8281 419.8281 419.8281 419.8281 419.8281 419.8281
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## 420.0328 420.0328 420.0328 420.0328 420.0328 420.0328 420.0328 420.0328
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## 420.0328 420.0328 420.0328 420.0328 420.0328 420.0328 420.0328 420.0328
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## 420.0328 420.0328 420.0328 420.2376 420.2376 420.2376 420.2376 420.2376
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## 420.2376 420.2376 420.2376 420.2376 420.2376 420.2376 420.2376 420.2376
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## 420.2376 420.2376 420.2376 420.2376 420.2376 420.2376 420.2376 420.2376
##     3497     3498     3499     3500     3501     3502     3503     3504
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##     3505     3506     3507     3508     3509     3510     3511     3512
## 420.2376 420.2376 420.4556 420.4556 420.4556 420.4556 420.4556 420.4556
##     3513     3514     3515     3516     3517     3518     3519     3520
## 420.4556 420.4556 420.4556 420.4556 420.4556 420.4556 420.4556 420.4556
##     3521     3522     3523     3524     3525     3526     3527     3528
## 420.4556 420.4556 420.4556 420.4556 420.4556 420.4556 420.4556 420.4556
##     3529     3530     3531     3532     3533     3534     3535     3536
## 420.4556 420.4556 420.4556 420.4556 420.4556 420.4556 420.4556 420.4556
##     3537     3538     3539     3540     3541     3542     3543     3544
## 420.6604 420.6604 420.6604 420.6604 420.6604 420.6604 420.6604 420.6604
##     3545     3546     3547     3548     3549     3550     3551     3552
## 420.6604 420.6604 420.6604 420.6604 420.6604 420.6604 420.6604 420.6604
##     3553     3554     3555     3556     3557     3558     3559     3560
## 420.6604 420.6604 420.6604 420.6604 420.6604 420.6604 420.6604 420.6604
##     3561     3562     3563     3564     3565     3566     3567     3568
## 420.6604 420.6604 420.6604 420.6604 420.6604 420.6604 420.6604 420.8651
##     3569     3570     3571     3572     3573     3574     3575     3576
## 420.8651 420.8651 420.8651 420.8651 420.8651 420.8651 420.8651 420.8651
##     3577     3578     3579     3580     3581     3582     3583     3584
## 420.8651 420.8651 420.8651 420.8651 420.8651 420.8651 420.8651 420.8651
##     3585     3586     3587     3588     3589     3590     3591     3592
## 420.8651 420.8651 420.8651 420.8651 420.8651 420.8651 420.8651 420.8651
##     3593     3594     3595     3596     3597     3598     3599     3600
## 420.8651 420.8651 420.8651 420.8651 420.8651 421.0253 421.0253 421.0253
##     3601     3602     3603     3604     3605     3606     3607     3608
## 421.0253 421.0253 421.0253 421.0253 421.0253 421.0253 421.0253 421.0253
##     3609     3610     3611     3612     3613     3614     3615     3616
## 421.0253 421.0253 421.0253 421.0253 421.0253 421.0253 421.0253 421.0253
##     3617     3618     3619     3620     3621     3622     3623     3624
## 421.0253 421.0253 421.0253 421.0253 421.0253 421.0253 421.0253 421.0253
##     3625     3626     3627     3628     3629     3630     3631     3632
## 421.0253 421.0253 421.0253 421.0253 421.2330 421.2330 421.2330 421.2330
##     3633     3634     3635     3636     3637     3638     3639     3640
## 421.2330 421.2330 421.2330 421.2330 421.2330 421.2330 421.2330 421.2330
##     3641     3642     3643     3644     3645     3646     3647     3648
## 421.2330 421.2330 421.2330 421.2330 421.2330 421.2330 421.2330 421.2330
##     3649     3650     3651     3652     3653     3654     3655     3656
## 421.2330 421.2330 421.2330 421.2330 421.2330 421.2330 421.2330 421.2330
##     3657     3658     3659     3660     3661     3662     3663     3664
## 421.2330 421.2330 421.2330 421.4378 421.4378 421.4378 421.4378 421.4378
##     3665     3666     3667     3668     3669     3670     3671     3672
## 421.4378 421.4378 421.4378 421.4378 421.4378 421.4378 421.4378 421.4378
##     3673     3674     3675     3676     3677     3678     3679     3680
## 421.4378 421.4378 421.4378 421.4378 421.4378 421.4378 421.4378 421.4378
##     3681     3682     3683     3684     3685     3686     3687     3688
## 421.4378 421.4378 421.4378 421.4378 421.4378 421.4378 421.4378 421.4378
##     3689     3690     3691     3692     3693     3694     3695     3696
## 421.6486 421.6486 421.6486 421.6486 421.6486 421.6486 421.6486 421.6486
##     3697     3698     3699     3700     3701     3702     3703     3704
## 421.6486 421.6486 421.6486 421.6486 421.6486 421.6486 421.6486 421.6486
##     3705     3706     3707     3708     3709     3710     3711     3712
## 421.6486 421.6486 421.6486 421.6486 421.6486 421.6486 421.6486 421.6486
##     3713     3714     3715     3716     3717     3718     3719     3720
## 421.6486 421.6486 421.6486 421.6486 421.6486 421.6486 421.6486 421.8534
```

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##     3721     3722     3723     3724     3725     3726     3727     3728
## 421.8534 421.8534 421.8534 421.8534 421.8534 421.8534 421.8534 421.8534
##     3729     3730     3731     3732     3733     3734     3735     3736
## 421.8534 421.8534 421.8534 421.8534 421.8534 421.8534 421.8534 421.8534
##     3737     3738     3739     3740     3741     3742     3743     3744
## 421.8534 421.8534 421.8534 421.8534 421.8534 421.8534 421.8534 421.8534
##     3745     3746     3747     3748     3749     3750     3751     3752
## 421.8534 421.8534 421.8534 421.8534 421.8534 422.0581 422.0581 422.0581
##     3753     3754     3755     3756     3757     3758     3759     3760
## 422.0581 422.0581 422.0581 422.0581 422.0581 422.0581 422.0581 422.0581
##     3761     3762     3763     3764     3765     3766     3767     3768
## 422.0581 422.0581 422.0581 422.0581 422.0581 422.0581 422.0581 422.0581
##     3769     3770     3771     3772     3773     3774     3775     3776
## 422.0581 422.0581 422.0581 422.0581 422.0581 422.0581 422.0581 422.0581
##     3777     3778     3779     3780     3781     3782     3783     3784
## 422.0581 422.0581 422.0581 422.0581 422.2881 422.2881 422.2881 422.2881
##     3785     3786     3787     3788     3789     3790     3791     3792
## 422.2881 422.2881 422.2881 422.2881 422.2881 422.2881 422.2881 422.2881
##     3793     3794     3795     3796     3797     3798     3799     3800
## 422.2881 422.2881 422.2881 422.2881 422.2881 422.2881 422.2881 422.2881
##     3801     3802     3803     3804     3805     3806     3807     3808
## 422.2881 422.2881 422.2881 422.2881 422.2881 422.2881 422.2881 422.2881
##     3809     3810     3811     3812     3813     3814     3815     3816
## 422.2881 422.2881 422.4928 422.4928 422.4928 422.4928 422.4928 422.4928
##     3817     3818     3819     3820     3821     3822     3823     3824
## 422.4928 422.4928 422.4928 422.4928 422.4928 422.4928 422.4928 422.4928
##     3825     3826     3827     3828     3829     3830     3831     3832
## 422.4928 422.4928 422.4928 422.4928 422.4928 422.4928 422.4928 422.4928
##     3833     3834     3835     3836     3837     3838     3839     3840
## 422.4928 422.4928 422.4928 422.4928 422.4928 422.4928 422.4928 422.4928
##     3841     3842     3843     3844     3845     3846     3847     3848
## 422.4928 422.6976 422.6976 422.6976 422.6976 422.6976 422.6976 422.6976
##     3849     3850     3851     3852     3853     3854     3855     3856
## 422.6976 422.6976 422.6976 422.6976 422.6976 422.6976 422.6976 422.6976
##     3857     3858     3859     3860     3861     3862     3863     3864
## 422.6976 422.6976 422.6976 422.6976 422.6976 422.6976 422.6976 422.6976
##     3865     3866     3867     3868     3869     3870     3871     3872
## 422.6976 422.6976 422.6976 422.6976 422.6976 422.6976 422.6976 422.6976
##     3873     3874     3875     3876     3877     3878     3879     3880
## 422.9156 422.9156 422.9156 422.9156 422.9156 422.9156 422.9156 422.9156
##     3881     3882     3883     3884     3885     3886     3887     3888
## 422.9156 422.9156 422.9156 422.9156 422.9156 422.9156 422.9156 422.9156
##     3889     3890     3891     3892     3893     3894     3895     3896
## 422.9156 422.9156 422.9156 422.9156 422.9156 422.9156 422.9156 422.9156
##     3897     3898     3899     3900     3901     3902     3903     3904
## 422.9156 422.9156 422.9156 422.9156 422.9156 422.9156 423.1204 423.1204
##     3905     3906     3907     3908     3909     3910     3911     3912
## 423.1204 423.1204 423.1204 423.1204 423.1204 423.1204 423.1204 423.1204
##     3913     3914     3915     3916     3917     3918     3919     3920
## 423.1204 423.1204 423.1204 423.1204 423.1204 423.1204 423.1204 423.1204
##     3921     3922     3923     3924     3925     3926     3927     3928
## 423.1204 423.1204 423.1204 423.1204 423.1204 423.1204 423.1204 423.1204
##     3929     3930     3931     3932     3933     3934     3935     3936
## 423.1204 423.1204 423.1204 423.1204 423.1204 423.3251 423.3251 423.3251
```

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##     3937     3938     3939     3940     3941     3942     3943     3944
## 423.3251 423.3251 423.3251 423.3251 423.3251 423.3251 423.3251 423.3251
##     3945     3946
## 423.3251 423.3251
```

```r
#Making predictions using the independent variables to forecast the dependent variable (trend)
model <- lm(trend ~ year + Season + month, data = co2_concentration)

new_data <- data.frame(
  year = rep(2025, 12),  # Assuming monthly data
  Season = c("Winter", "Winter", "Spring", "Spring", "Spring", "Summer", "Summer", "Summer", "Autumn",
  month = 1:12
)
predictions_2025 <- predict(model, newdata = new_data)
new_data$predicted_trend <- predictions_2025
print(new_data)
```

```
##    year Season month predicted_trend
## 1  2025 Winter     1        423.6930
## 2  2025 Winter     2        423.8978
## 3  2025 Spring     3        424.1086
## 4  2025 Spring     4        424.3134
## 5  2025 Spring     5        424.5181
## 6  2025 Summer     6        424.7481
## 7  2025 Summer     7        424.9528
## 8  2025 Summer     8        425.1576
## 9  2025 Autumn     9        425.3756
## 10 2025 Autumn    10        425.5803
## 11 2025 Autumn    11        425.7851
## 12 2025 Winter    12        425.9453
```