Time Series Analysis of Seasonal Weather Patterns in the Four Corners Region of the United States

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## Problem Statement

In the past decades there has been a noticeable increase in the volatility of weather patterns in the Western United States. In particular, the four corners region (Arizona, Colorado, New Mexico and Utah) have experienced prolonged drought, monsoon rainfall, and a noticeable increase in the intensity and duration of heat waves. To better understand seasonal weather patterns in the region this report focuses on a time-series analysis of mean monthly temperature, total monthly precipitation and total monthly snowfall in the period between January 1, 1970 and December 31, 2019. Time series analysis was conducted using a Seasonal Autoregressive Integrated Moving Average (SARIMA) model. The primary research questions addressed are as follows:

* Is there a noticeable trend in monthly mean temperature, total monthly precipitation, or total monthly snowfall?
* Is the SARIMA model an effective means of visualizing and predicting mean monthly temperature, total monthly precipitation and total monthly snowfall in the four corners region of the United States.

## Data Collection

Data for the analysis was sourced from the Global Historical Climatology Network (GHCN). The GHCN is an integrated database of daily climate summaries from land surface weather stations across the globe. GHCN data contain records from more than 100,000 stations in 180 countries and territories. All records are subject to a common suite of quality assurance reviews to maintain accuracy through uniformity of reporting standards. All GHCN records include but are not limited to the following daily variables:

* Daily maximum and daily minimum temperature
* Total daily precipitation
* Total daily snowfall

### US Collection of GHCN Data

Daily weather records from the United States are compiled from a dozen separate datasets archived at the National Centers of Environmental Information (NCEI), a branch of the National Oceanic and Atmospheric Administration (NOAA). NCEI is responsible for hosting and providing access to one of the most significant stores of environmental data in existence with over 37 petabytes of oceanic, atmospheric and geophysical data (National Centers for Environmental Information, 2019).

### Variables Included in the Model

* Average Daily Temperature (degrees Fahrenheit)
* Total Daily Precipitation (inches)
* Total Daily Snowfall (inches)

For more detailed information on each of the variables listed above please see (Appendix A)

## Data Set Features and Data Preparation

### Data Set Summary

The data used in this report were observed at weather stations in four major cities located in the southwestern United States, specifically Phoenix, AZ, Denver, CO, Albuquerque, NM and Salt Lake City, UT. Data was collected via land-based weather stations at major airports in each city with the exception being data collected in Denver, Colorado. Weather observations for Denver were collected using a land-based weather station located in the Sand Creek Open Space in the Denver Central Park Region in the Northwest corner of the city. Data for each city was downloaded as comma separated value (csv) files. Exploration of key features of the data sets, data cleansing and initial visualization was carried out using the “DataExplorer” library available in R.

### Data Discovery and Cleansing Process

Each of the four data sets was examined prior to conducting time series analysis. Initial analysis focused on locating and replacing missing values, transforming data to appropriate types for analysis and aggregating daily measurements.

#### Summary statistics for each data set

# Albuquerque  
summary(ABQ)

## STATION NAME   
## USW00023050:18262 ALBUQUERQUE INTERNATIONAL AIRPORT, NM US:18262   
##   
##   
##   
##   
##   
##   
## DATE PRCP SNOW TAVG   
## 1970-01-01: 1 Min. :0.0000 Min. : 0.00000 Min. : 0.00   
## 1970-01-02: 1 1st Qu.:0.0000 1st Qu.: 0.00000 1st Qu.:45.00   
## 1970-01-03: 1 Median :0.0000 Median : 0.00000 Median :60.00   
## 1970-01-04: 1 Mean :0.0247 Mean : 0.02759 Mean :58.94   
## 1970-01-05: 1 3rd Qu.:0.0000 3rd Qu.: 0.00000 3rd Qu.:74.00   
## 1970-01-06: 1 Max. :1.9200 Max. :11.30000 Max. :89.00   
## (Other) :18256 NA's :251 NA's :13120   
## TMAX TMIN   
## Min. : 6.00 Min. :-17.00   
## 1st Qu.: 56.00 1st Qu.: 31.00   
## Median : 72.00 Median : 44.00   
## Mean : 70.55 Mean : 44.35   
## 3rd Qu.: 86.00 3rd Qu.: 59.00   
## Max. :107.00 Max. : 78.00   
##

# Denver   
summary(DEN)

## STATION NAME DATE   
## USW00023062:18262 DENVER CENTRAL PARK, CO US:18262 1970-01-01: 1   
## 1970-01-02: 1   
## 1970-01-03: 1   
## 1970-01-04: 1   
## 1970-01-05: 1   
## 1970-01-06: 1   
## (Other) :18256   
## PRCP SNOW TAVG TMAX   
## Min. :0.0000 Min. : 0.0000 Mode:logical Min. : -9.0   
## 1st Qu.:0.0000 1st Qu.: 0.0000 NA's:18262 1st Qu.: 50.0   
## Median :0.0000 Median : 0.0000 Median : 66.0   
## Mean :0.0423 Mean : 0.1497 Mean : 64.8   
## 3rd Qu.:0.0000 3rd Qu.: 0.0000 3rd Qu.: 81.0   
## Max. :6.4700 Max. :23.6000 Max. :104.0   
## NA's :1 NA's :19   
## TMIN   
## Min. :-25.00   
## 1st Qu.: 25.00   
## Median : 36.00   
## Mean : 36.95   
## 3rd Qu.: 52.00   
## Max. : 72.00   
## NA's :6

# Phoenix  
summary(PHX)

## STATION NAME LATITUDE   
## USW00023183:18262 PHOENIX AIRPORT, AZ US:18262 Min. :33.43   
## 1st Qu.:33.43   
## Median :33.43   
## Mean :33.43   
## 3rd Qu.:33.43   
## Max. :33.43   
##   
## LONGITUDE ELEVATION DATE PRCP   
## Min. :-112 Min. :337.4 1970-01-01: 1 Min. :0.00000   
## 1st Qu.:-112 1st Qu.:337.4 1970-01-02: 1 1st Qu.:0.00000   
## Median :-112 Median :337.4 1970-01-03: 1 Median :0.00000   
## Mean :-112 Mean :337.4 1970-01-04: 1 Mean :0.02078   
## 3rd Qu.:-112 3rd Qu.:337.4 1970-01-05: 1 3rd Qu.:0.00000   
## Max. :-112 Max. :337.4 1970-01-06: 1 Max. :3.30000   
## (Other) :18256   
## SNOW TAVG TMAX TMIN   
## Min. :0.0 Min. : 0.00 Min. : 43.00 Min. :19.00   
## 1st Qu.:0.0 1st Qu.: 63.00 1st Qu.: 73.00 1st Qu.:50.00   
## Median :0.0 Median : 77.00 Median : 88.00 Median :62.00   
## Mean :0.0 Mean : 76.44 Mean : 86.88 Mean :62.71   
## 3rd Qu.:0.0 3rd Qu.: 91.00 3rd Qu.:101.00 3rd Qu.:76.00   
## Max. :0.2 Max. :106.00 Max. :122.00 Max. :96.00   
## NA's :7255 NA's :13128

# Salt Lake City   
summary(SLC)

## STATION NAME   
## USW00024127:18262 SALT LAKE CITY INTERNATIONAL AIRPORT, UT US:18262   
##   
##   
##   
##   
##   
##   
## DATE PRCP SNOW TAVG   
## 1970-01-01: 1 Min. :0.00000 Min. : 0.000 Min. : 0.00   
## 1970-01-02: 1 1st Qu.:0.00000 1st Qu.: 0.000 1st Qu.:40.00   
## 1970-01-03: 1 Median :0.00000 Median : 0.000 Median :54.00   
## 1970-01-04: 1 Mean :0.04391 Mean : 0.155 Mean :54.98   
## 1970-01-05: 1 3rd Qu.:0.01000 3rd Qu.: 0.000 3rd Qu.:72.00   
## 1970-01-06: 1 Max. :2.27000 Max. :13.800 Max. :92.00   
## (Other) :18256 NA's :8 NA's :13119   
## TMAX TMIN   
## Min. : 2.00 Min. :-15.00   
## 1st Qu.: 47.00 1st Qu.: 30.00   
## Median : 63.00 Median : 41.00   
## Mean : 64.35 Mean : 41.97   
## 3rd Qu.: 83.00 3rd Qu.: 56.00   
## Max. :107.00 Max. : 81.00   
##

#### Structure of Each Data Set (Number of Observations and Variable Type)

## 'data.frame': 18262 obs. of 8 variables:  
## $ STATION: Factor w/ 1 level "USW00023050": 1 1 1 1 1 1 1 1 1 1 ...  
## $ NAME : Factor w/ 1 level "ALBUQUERQUE INTERNATIONAL AIRPORT, NM US": 1 1 1 1 1 1 1 1 1 1 ...  
## $ DATE : Factor w/ 18262 levels "1970-01-01","1970-01-02",..: 1 2 3 4 5 6 7 8 9 10 ...  
## $ PRCP : num 0 0 0 0 0 0 0 0 0 0 ...  
## $ SNOW : num 0 0 0 0 0 0 0 0 0 0 ...  
## $ TAVG : int NA NA NA NA NA NA NA NA NA NA ...  
## $ TMAX : int 35 31 33 31 35 31 35 41 44 53 ...  
## $ TMIN : int 17 8 6 10 10 4 3 16 14 29 ...

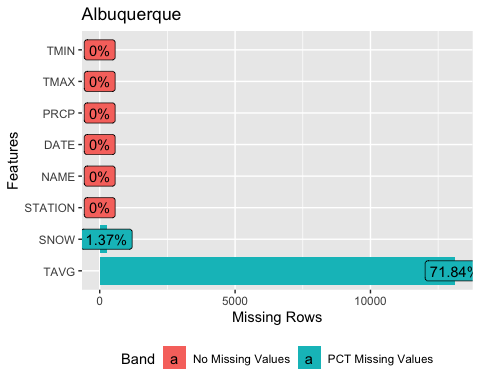
## 'data.frame': 18262 obs. of 8 variables:  
## $ STATION: Factor w/ 1 level "USW00023062": 1 1 1 1 1 1 1 1 1 1 ...  
## $ NAME : Factor w/ 1 level "DENVER CENTRAL PARK, CO US": 1 1 1 1 1 1 1 1 1 1 ...  
## $ DATE : Factor w/ 18262 levels "1970-01-01","1970-01-02",..: 1 2 3 4 5 6 7 8 9 10 ...  
## $ PRCP : num 0 0 0 0.02 0.04 0 0 0 0 0 ...  
## $ SNOW : num 0 0 0 0.3 0.6 0 0 0 0 0 ...  
## $ TAVG : logi NA NA NA NA NA NA ...  
## $ TMAX : int 28 30 30 33 14 22 23 22 38 52 ...  
## $ TMIN : int 10 10 3 1 -6 -10 -5 -8 1 23 ...

## 'data.frame': 18262 obs. of 11 variables:  
## $ STATION : Factor w/ 1 level "USW00023183": 1 1 1 1 1 1 1 1 1 1 ...  
## $ NAME : Factor w/ 1 level "PHOENIX AIRPORT, AZ US": 1 1 1 1 1 1 1 1 1 1 ...  
## $ LATITUDE : num 33.4 33.4 33.4 33.4 33.4 ...  
## $ LONGITUDE: num -112 -112 -112 -112 -112 ...  
## $ ELEVATION: num 337 337 337 337 337 ...  
## $ DATE : Factor w/ 18262 levels "1970-01-01","1970-01-02",..: 1 2 3 4 5 6 7 8 9 10 ...  
## $ PRCP : num 0 0 0 0 0 0 0 0 0 0 ...  
## $ SNOW : num 0 0 0 0 0 0 0 0 0 0 ...  
## $ TAVG : int NA NA NA NA NA NA NA NA NA NA ...  
## $ TMAX : int 57 55 59 61 58 59 61 67 68 64 ...  
## $ TMIN : int 31 31 26 35 28 28 33 32 42 37 ...

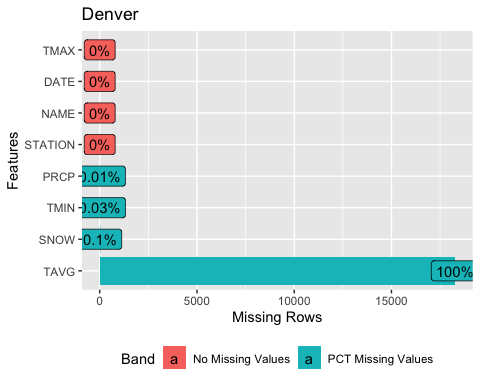
## 'data.frame': 18262 obs. of 8 variables:  
## $ STATION: Factor w/ 1 level "USW00024127": 1 1 1 1 1 1 1 1 1 1 ...  
## $ NAME : Factor w/ 1 level "SALT LAKE CITY INTERNATIONAL AIRPORT, UT US": 1 1 1 1 1 1 1 1 1 1 ...  
## $ DATE : Factor w/ 18262 levels "1970-01-01","1970-01-02",..: 1 2 3 4 5 6 7 8 9 10 ...  
## $ PRCP : num 0 0 0 0 0 0 0 0 0 0.2 ...  
## $ SNOW : num 0 0 0 0 0 0 0 0 0 0.7 ...  
## $ TAVG : int NA NA NA NA NA NA NA NA NA NA ...  
## $ TMAX : int 26 25 30 30 27 26 25 29 43 44 ...  
## $ TMIN : int 6 8 12 11 10 7 6 8 24 34 ...

#### Visualize Missing Values From Each Dataset

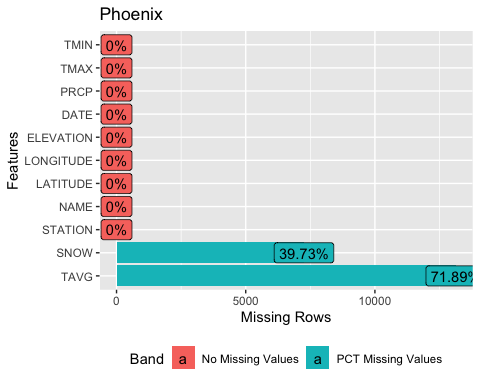
# Albuquerque  
plot\_missing(ABQ, title = "Albuquerque", group=c("No Missing Values"=0,   
 "PCT Missing Values"= 1))



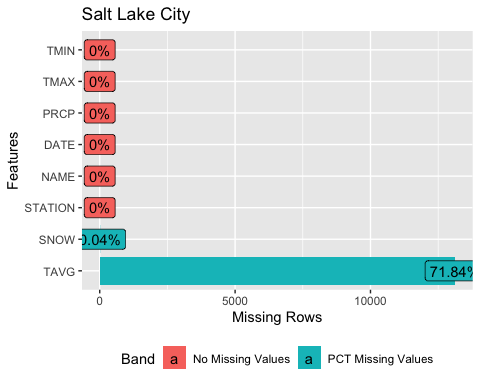
# Denver  
plot\_missing(DEN, title = "Denver", group=c("No Missing Values"=0,   
 "PCT Missing Values"= 1))



# Phoenix  
plot\_missing(PHX, title = "Phoenix", group=c("No Missing Values"=0,  
 "PCT Missing Values"= 1))



# Salt Lake City   
plot\_missing(SLC, title = "Salt Lake City ", group=c("No Missing Values"=0,   
 "PCT Missing Values"= 1))



#### Replace Missing Values

The above graphs show that each of the data sets are missing observations for one or more values. To avoid the effects of outliers, missing values for TMIN, TMAX, PRCP and SNOW will be replaced with the median value for each of the respective variables. According GHCN Daily TAVG is calculated by taking the mean value for daily observations of TMAX and TMIN and rounding up to the nearest integer, That is daily . Therefore, missing values for TAVG will be replaced using this formula. For readability only the replacement of missing values from the “ABQ” data set is detailed below. Please see the .rmd version of this report for a more in depth explanation of the replacement process.

# replace missing values in ABQ  
# replace NA's in the SNOW column with the median snowfall   
ABQ$SNOW[is.na(ABQ$SNOW)] <- median(ABQ$SNOW, na.rm = T)  
# replace the missing values for TAVG  
ABQTEMP <- data.frame(ABQ$TMAX, ABQ$TMIN)  
ind <- which(is.na(ABQ), arr.ind=TRUE)  
# all temperatures are given as whole numbers in dataset so round the mean  
ABQ[ind] <- ceiling(rowMeans(ABQTEMP, na.rm=TRUE)[ind[,1]])  
#check to ensure replacement   
profile\_missing(ABQ)

## feature num\_missing pct\_missing  
## 1 STATION 0 0  
## 2 NAME 0 0  
## 3 DATE 0 0  
## 4 PRCP 0 0  
## 5 SNOW 0 0  
## 6 TAVG 0 0  
## 7 TMAX 0 0  
## 8 TMIN 0 0

#### Preparing Data for Time Series Analysis

# transform date column from factor to date data type in each data set  
ABQ <- transform(ABQ, DATE = as.Date(DATE))  
DEN <- transform(DEN, DATE = as.Date(DATE))  
PHX <- transform(PHX, DATE = as.Date(DATE))  
SLC <- transform(SLC, DATE = as.Date(DATE))  
#verify changes   
ABQ\_DELTA <- sapply(ABQ, class)  
DEN\_DELTA <- sapply(DEN, class)  
PHX\_DELTA <- sapply(PHX, class)  
SLC\_DELTA <- sapply(SLC, class)

ABQ\_DELTA

## STATION NAME DATE PRCP SNOW TAVG TMAX   
## "factor" "factor" "Date" "numeric" "numeric" "numeric" "integer"   
## TMIN   
## "integer"

#### Aggregate Data for Monthly Analysis

# Albuquerque  
# create column month year to aggregate data for time series   
ABQ$MONTH\_YEAR <- floor\_date(ABQ$DATE,"month")  
# create aggregated dataset using MONTH\_YEAR COLUMN  
ABQ\_AGG <- ABQ %>%  
 group\_by(MONTH\_YEAR)%>%  
 dplyr::summarize(Monthly\_Avg\_Temp = mean(TAVG),  
 Monthly\_Rainfall=sum(PRCP), Monthly\_Snowfall=sum(SNOW)) %>%  
 as.data.frame()  
head(ABQ\_AGG)

## MONTH\_YEAR Monthly\_Avg\_Temp Monthly\_Rainfall Monthly\_Snowfall  
## 1 1970-01-01 34.74194 0.00 0.0  
## 2 1970-02-01 43.14286 0.27 2.7  
## 3 1970-03-01 44.22581 0.42 3.3  
## 4 1970-04-01 52.76667 0.05 0.0  
## 5 1970-05-01 66.35484 0.33 0.0  
## 6 1970-06-01 72.83333 0.40 0.0

### Analysis Using Seasonal Autoregressive Integrated Moving Average SARIMA Model

#### What is a SARIMA Model?

A SARIMA model is the seasonal flavor of the autoregressive integrated moving average (ARIMA) model. ARIMA and SARIMA models are a statistical technique used to analyze times series data and in certain cases predict future values. The goal of autoregressive models is to predict future values of the target variable by regressing against past observations of the variable. That is, lagged values of the target variable are used as independent variables “x’s” in the regression equation (Yiu, 2020). Seasonal autoregressive models are used to perform similar analysis while accounting for any seasonality observed in the time series being analyzed. ARIMA and SARIMA models also incorporate differencing to correct for data that is not stationary and a moving average component that includes errors in previous predictions as a parameter in the model. To better understand the method a brief summary of each component is given below.

#### Autoregressive (p)

Considering an observed value “Y” to be a linear function of it’s past observations a simple representation of the regression equation is as follows.

By tweaking this equation we can attempt to predict future values of Y.

The above equation represents what is commonly referred to as an AR(1) model. An autoregressive model using a single lag to predict future values of Y (Yiu, 2020).

#### Integrated (d)

When conducting times series analysis an important step is ensuring that time series data is stationary. Stationary time series data has a more stable mean and variance. That is the mean and variance of the data are consistent over time leading to a more robust model. Performing one or more differencing steps on time series data helps to ensure stationarity. In ARIMA and SARIMA modeling this step can be performed as follows.

#### Moving Average (q)

Moving average(MA) is similar to the autoregressive step in that it uses past values (lags) to predict future outcomes. The difference is that the MA method uses previous error terms in the regression model as parameters for predicting future values. Error terms or “E” represent random deviations between values of the target variable fitted by the model and actual observations at each lag.

For a simple moving average model the above equation can then be modified to include the average of “Y.” Thus errors at each lag push the average of Y in the positive or negative direction adjusting the moving average of Y.

#### Seasonal (PDQ)[Seasonality]

When constructing an ARIMA model it’s important to note the presence of cyclical or predictable patterns in the data being analyzed. Many times these patterns represent seasonality. If you wanted to model the sale of baseball tickets on a monthly basis you would notice a sharp decrease to zero tickets sold between the months of February and March. That’s because this is the off-season for baseball. The off-season begins and ends at roughly the same time every year. So when using an ARIMA model we should account for this seasonality by adding seasonal parameters to the model. Using the auto.arima function in R approximates the seasonal parameters of an ARIMA model helping to account for seasonality and improve model performance. An abstraction of a SARIMA model and it’s parameters as output by the auto.arima function is given below.

### Preparing to Model the Data Using SARIMA

The first step when using the auto.arima function in R is to transform the data being analyzed into a “time series object”. Time series objects will be created for mean monthly temperature (degrees Fahrenheit), total monthly precipitation (inches) and total monthly snowfall (inches) for each of the four locations being analyzed.

# create time series objects for mean monthly temperature   
ABQ\_TS\_TEMP <- ts(ABQ\_AGG[, 2], start= c(1970,1), end= c(2019,12), frequency = 12)  
DEN\_TS\_TEMP <- ts(DEN\_AGG[, 2], start= c(1970,1), end= c(2019,12), frequency = 12)  
PHX\_TS\_TEMP <- ts(PHX\_AGG[, 2], start= c(1970,1), end= c(2019,12), frequency = 12)  
SLC\_TS\_TEMP <- ts(SLC\_AGG[, 2], start= c(1970,1), end= c(2019,12), frequency = 12)  
# create time series objects for total monthly precipitation   
ABQ\_TS\_PRCP <- ts(ABQ\_AGG[, 3], start=c(1970, 1), end=c(2019,12), frequency=12)  
DEN\_TS\_PRCP <- ts(DEN\_AGG[, 3], start=c(1970, 1), end=c(2019,12), frequency=12)  
PHX\_TS\_PRCP <- ts(PHX\_AGG[, 3], start=c(1970, 1), end=c(2019,12), frequency=12)  
SLC\_TS\_PRCP <- ts(SLC\_AGG[, 3], start=c(1970, 1), end=c(2019,12), frequency=12)  
# create time series objects for total monthly snowfall   
ABQ\_TS\_SNOW <- ts(ABQ\_AGG[, 4], start=c(1970,1), end=c(2019,12), frequency=12)  
DEN\_TS\_SNOW <- ts(DEN\_AGG[, 4], start=c(1970,1), end=c(2019,12), frequency=12)  
PHX\_TS\_SNOW <- ts(PHX\_AGG[, 4], start=c(1970,1), end=c(2019,12), frequency=12)  
SLC\_TS\_SNOW <- ts(SLC\_AGG[, 4], start=c(1970,1), end=c(2019,12), frequency=12)

#### Test That the Time Series Data Are Stationary

Time series may be considered stationary if they have no significant trend, constant variance over time and a constant autocorrelation structure over time (Zach, 2021). One method of testing whether times series data are stationary in R is to use the adf.test function from the tseries library. The adf.test function performs an augmented Dickey-Fuller test on the specified time series object. The augmented Dickey-Fuller Test gives the following null hypothesis, alternate hypothesis and confidence level.

$$H\_o: \space The \space time \space series \space is \space non-stationary.$$

$$H\_A: \space the \space time \space series \space is \space stationary$$

When applied to each of the time series above the output of the adf.test function showed the null hypothesis should be rejected. Instead the alternate hypothesis that the data are stationary should be accepted. The adf.test function as applied to the “ABQ\_TS\_TEMP” time series object is given as an example below. For a more detailed explanation of the process please see the .rmd version of this report.

# perform the ADF test for ABQ  
adf.test(ABQ\_TS\_TEMP)

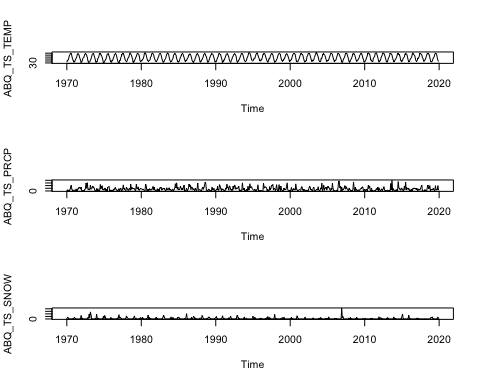
## Warning in adf.test(ABQ\_TS\_TEMP): p-value smaller than printed p-value

##   
## Augmented Dickey-Fuller Test  
##   
## data: ABQ\_TS\_TEMP  
## Dickey-Fuller = -15.857, Lag order = 8, p-value = 0.01  
## alternative hypothesis: stationary

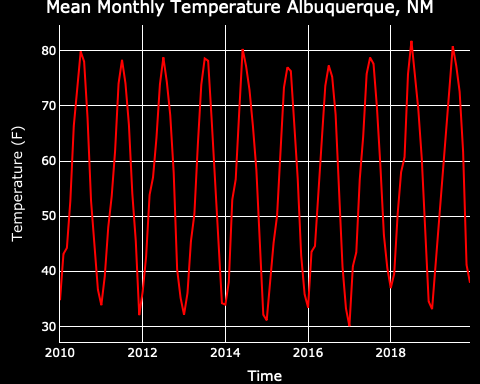
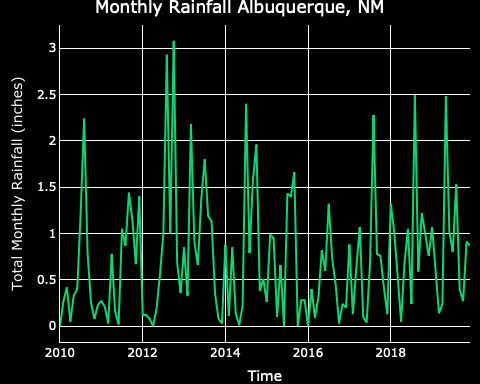
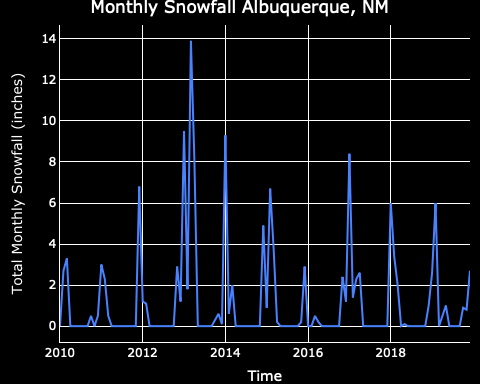
#### Visualize the Data

An important step in time series analysis is to visually inspect the data. Time series visualization allows for further assessment of whether the data are stationary, decomposition of time series attributes and inspection for anomalies in the data.

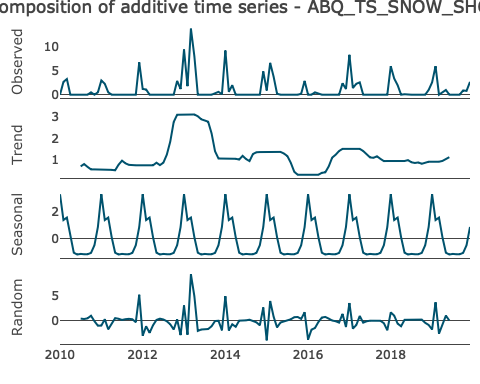
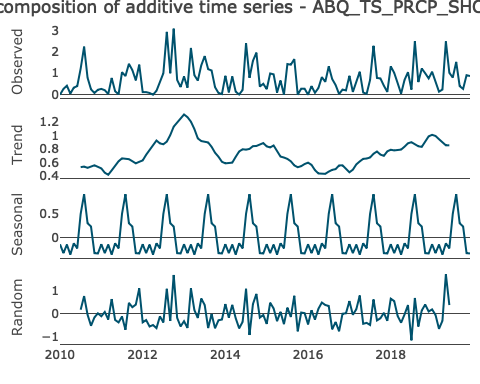
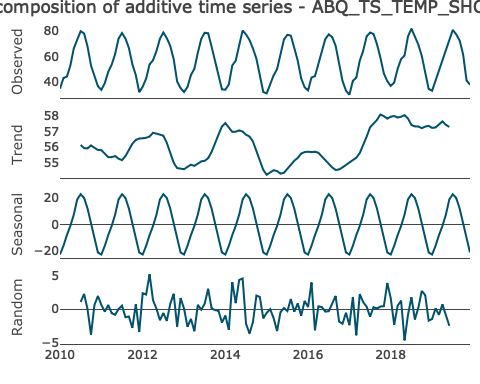
* High-level visual of the time series objects created for measurements from Albuquerque



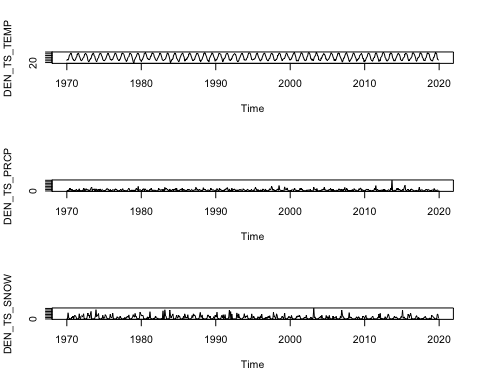
* Shortened time-span to allow for closer look at the behavior of each variable



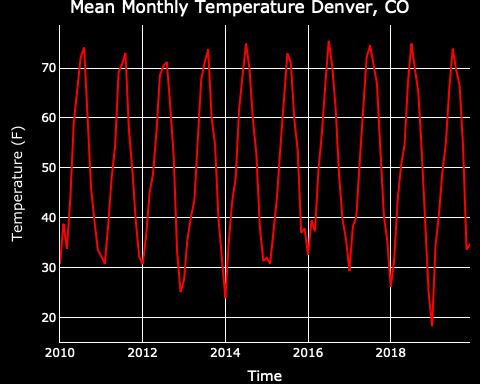
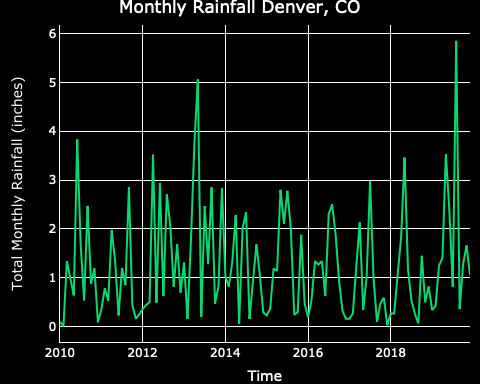
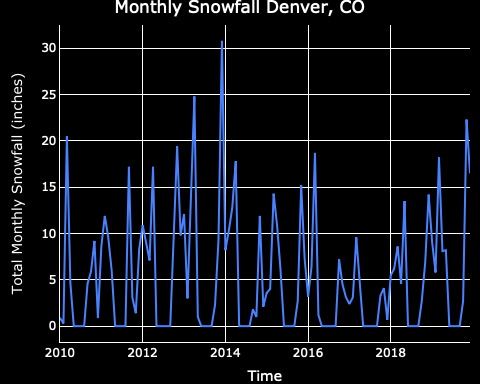
* Decomposition of time series from the city of Albuquerque shows that the series for mean monthly temperature, total monthly precipitation and total monthly snowfall each exhibit a strong seasonal component.Total monthly precipitation and total monthly snowfall both show much more variance in observed values over time. It’s worth noting that there seems to be an increase in mean monthly temperature around the year 2016.



* High-level visual of the time series objects created for measurements from Denver

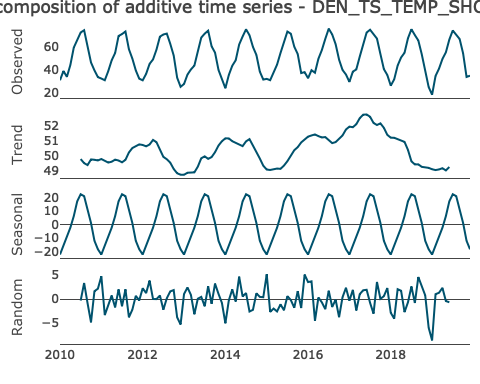


* Shortened time-span to allow for closer look at the behavior of each variable

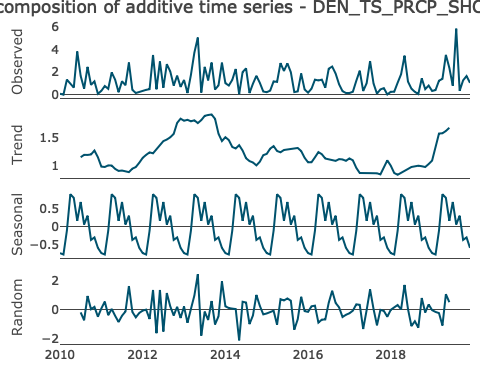


* Decomposition of time series from the city of Denver shows that the series for mean monthly temperature, total monthly precipitation and total monthly snowfall each exhibit a strong seasonal component similar to the time series data from Albuquerque. Examining the plots of the decomposed series below shows that the trend in each series seems to exhibit a somewhat cyclical pattern. Eluding to the fact that there may be a seasonal pattern occurring on a multi-year scale such as, the effects of the El Nino-Southern Oscillation cycle.

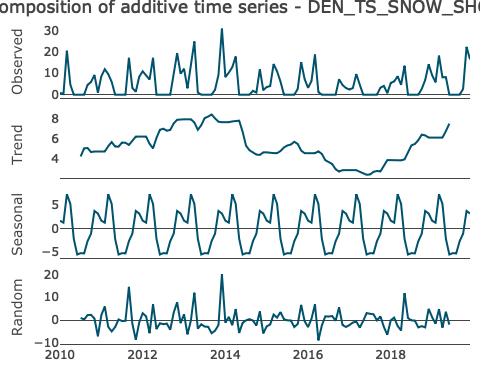
par(mfrow=c(1,3))  
ts\_decompose(DEN\_TS\_TEMP\_SHORT)



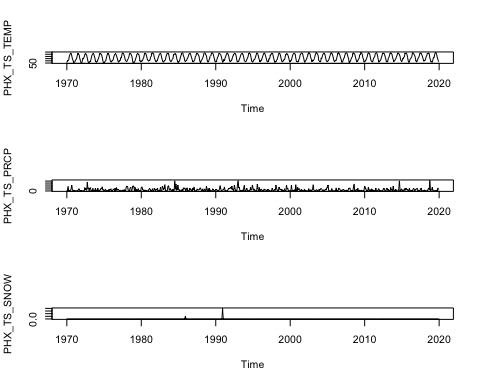
ts\_decompose(DEN\_TS\_PRCP\_SHORT)

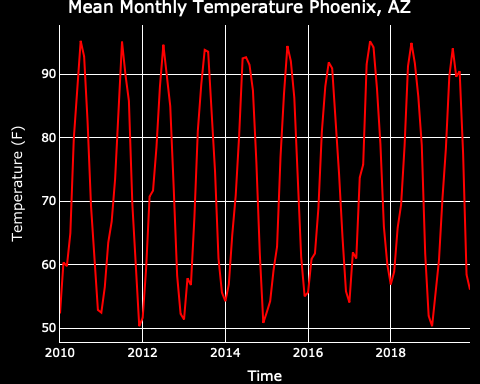
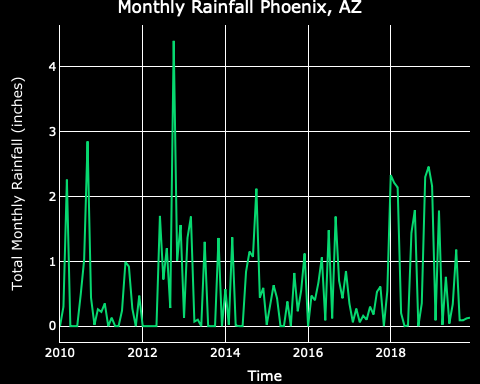
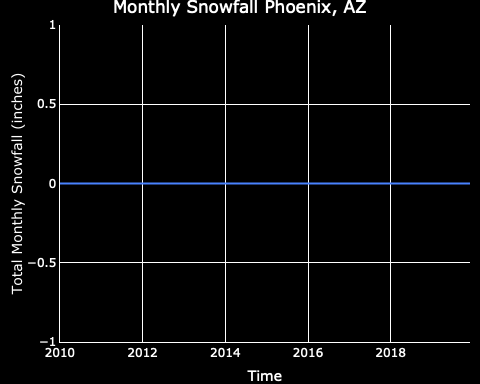


ts\_decompose(DEN\_TS\_SNOW\_SHORT)

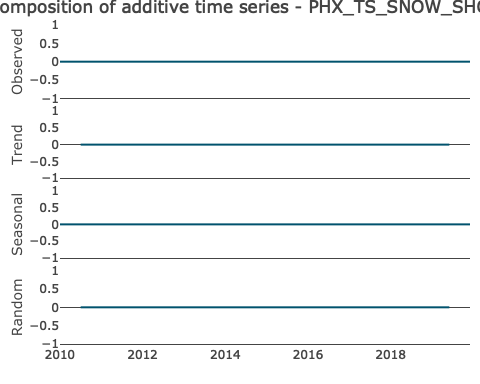
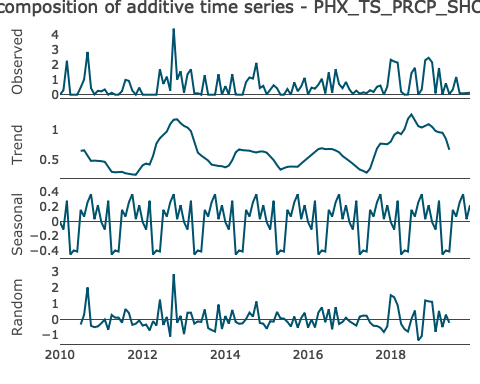
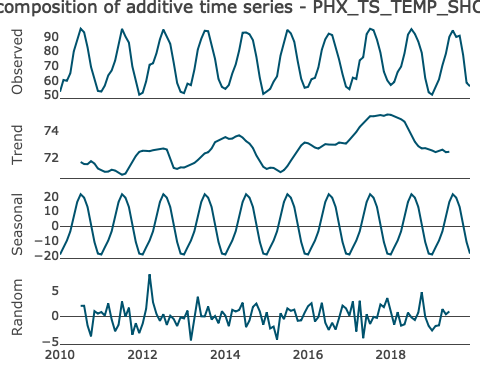


* High-level visual of the time series objects created for measurements from Phoenix

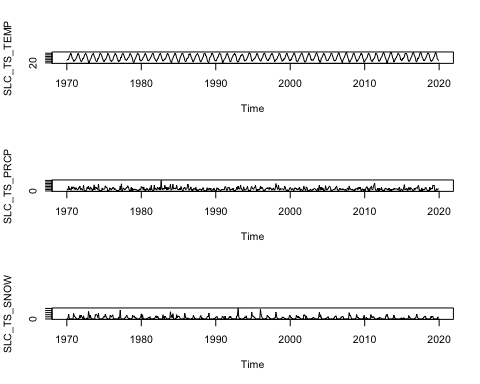


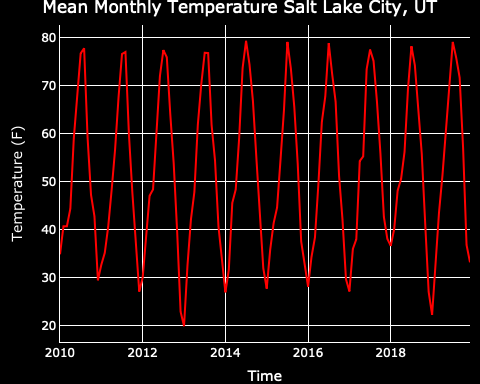
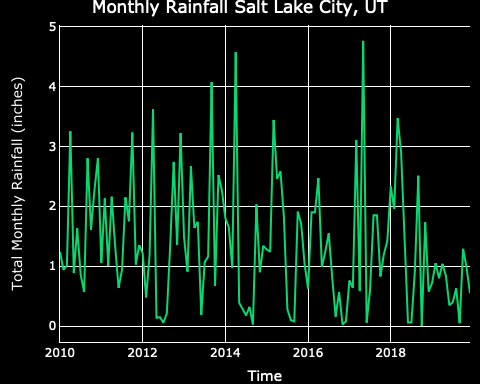
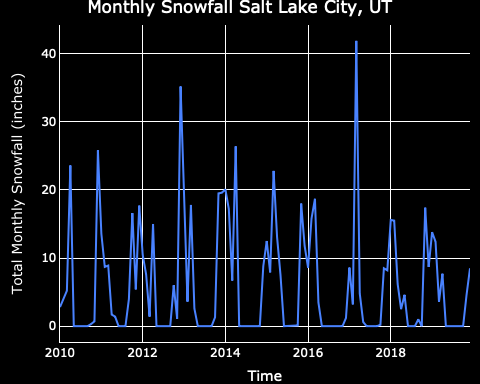


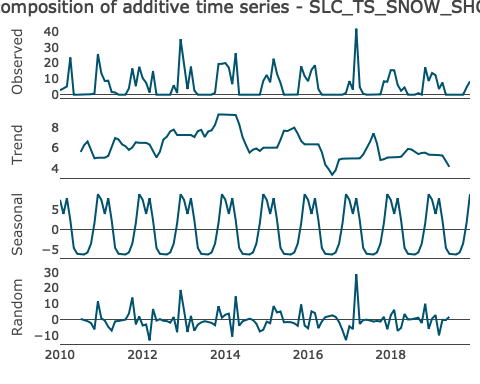
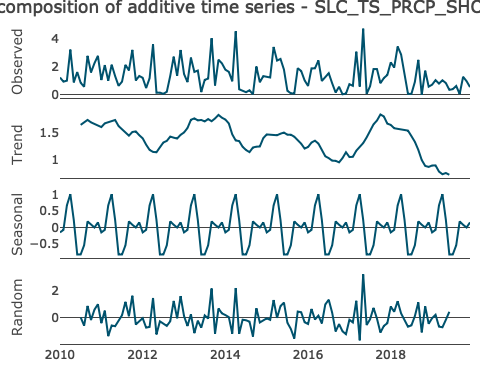
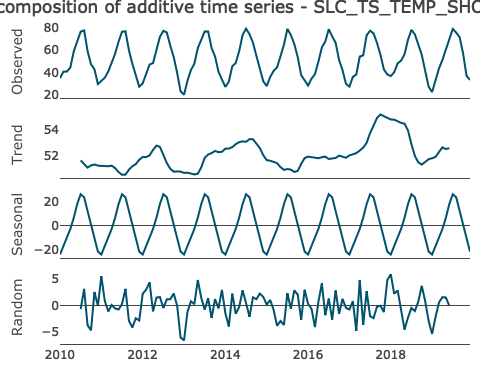
* Decomposition of time series from the city of Phoenix shows that the series for mean monthly temperature, total monthly precipitation and total monthly snowfall each exhibit a strong seasonal component similar to the time series data from both Denver and Albuquerque. Examining the plots of the decomposed series below it’s worth noting that there seems to be a slight upward trend in both mean monthly temperature and total monthly precipitation occurring around the year 2016. The trend in monthly precipitation may be attributed to a multi-year seasonal pattern, but the rising trend in mean monthly temperature appears at a glance to be more of a departure from the trend of past observations. The decomposition of the series for monthly snowfall confirms that it rarely snows in Phoenix. The series will be omitted from further analysis in this report.



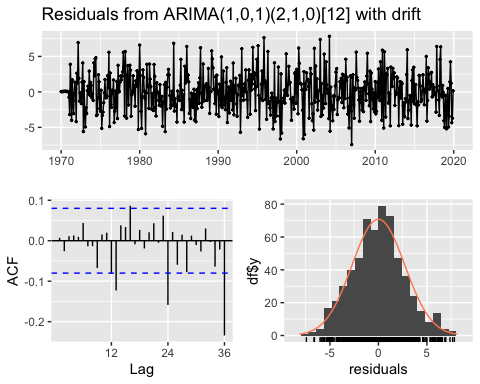
* High-level visual of the time series objects created for measurements from Salt Lake City



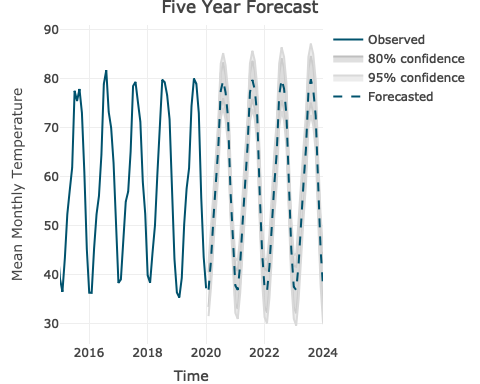


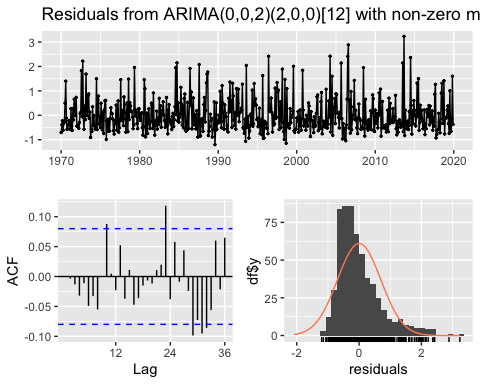


#### Create the SARIMA MODEL for Each Time Series



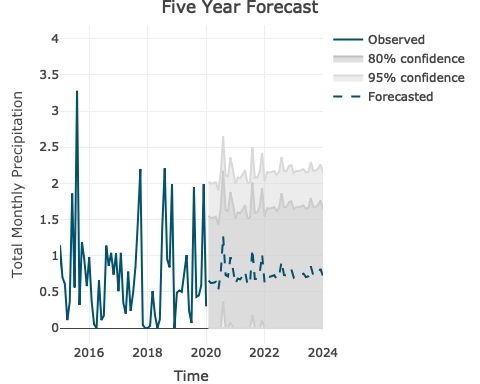
##   
## Ljung-Box test  
##   
## data: Residuals from ARIMA(1,0,1)(2,1,0)[12] with drift  
## Q\* = 45.23, df = 19, p-value = 0.0006364  
##   
## Model df: 5. Total lags used: 24

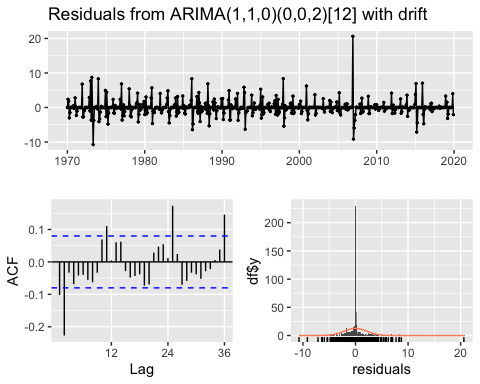




##   
## Ljung-Box test  
##   
## data: Residuals from ARIMA(0,0,2)(2,0,0)[12] with non-zero mean  
## Q\* = 24.845, df = 19, p-value = 0.1657  
##   
## Model df: 5. Total lags used: 24

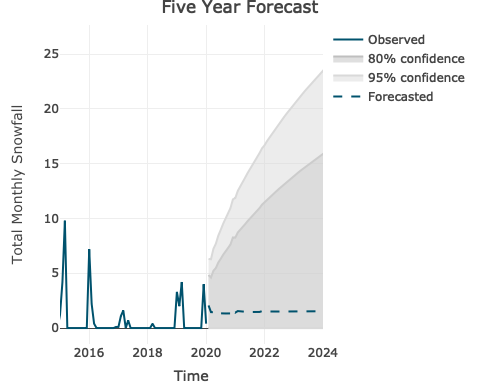
## Point Forecast Lo 80 Hi 80 Lo 95 Hi 95  
## Jan 2020 0.6553223 -0.23958421 1.550229 -0.7133191 2.023964  
## Feb 2020 0.6223902 -0.27588264 1.520663 -0.7513996 1.996180  
## Mar 2020 0.6258954 -0.27537937 1.527170 -0.7524854 2.004276  
## Apr 2020 0.6393342 -0.26194054 1.540609 -0.7390466 2.017715  
## May 2020 0.5239220 -0.37735272 1.425197 -0.8544587 1.902303  
## Jun 2020 0.7606930 -0.14058177 1.661968 -0.6176878 2.139074  
## Jul 2020 1.2732392 0.37196452 2.174514 -0.1051415 2.651620  
## Aug 2020 0.7322432 -0.16903155 1.633518 -0.6461376 2.110624  
## Sep 2020 0.7128794 -0.18839532 1.614154 -0.6655013 2.091260  
## Oct 2020 0.9790246 0.07774990 1.880299 -0.3993561 2.357405  
## Nov 2020 0.8181752 -0.08309958 1.719450 -0.5602056 2.196556  
## Dec 2020 0.6122808 -0.28899396 1.513556 -0.7661000 1.990662  
## Jan 2021 0.6834003 -0.23255117 1.599352 -0.7174266 2.084227  
## Feb 2021 0.6732062 -0.24285500 1.589267 -0.7277885 2.074201  
## Mar 2021 0.7219651 -0.19419423 1.638124 -0.6791797 2.123110  
## Apr 2021 0.7829976 -0.13316174 1.699157 -0.6181472 2.184142  
## May 2021 0.6008409 -0.31531846 1.517000 -0.8003039 2.001986  
## Jun 2021 0.6084830 -0.30767638 1.524642 -0.7926618 2.009628  
## Jul 2021 1.0953409 0.17918158 2.011500 -0.3058039 2.496486  
## Aug 2021 0.6786083 -0.23755104 1.594768 -0.7225365 2.079753  
## Sep 2021 0.6792589 -0.23690046 1.595418 -0.7218859 2.080404  
## Oct 2021 0.7571179 -0.15904140 1.673277 -0.6440269 2.158263  
## Nov 2021 1.0206645 0.10450515 1.936824 -0.3804803 2.421809  
## Dec 2021 0.6295184 -0.28664094 1.545678 -0.7716264 2.030663  
## Jan 2022 0.7168356 -0.22467919 1.658350 -0.7230870 2.156758  
## Feb 2022 0.7080854 -0.23361791 1.649789 -0.7321255 2.148296  
## Mar 2022 0.7177168 -0.22415520 1.659589 -0.7227521 2.158186  
## Apr 2022 0.7316662 -0.21020574 1.673538 -0.7088027 2.172135  
## May 2022 0.6742784 -0.26759355 1.616150 -0.7661905 2.114747  
## Jun 2022 0.7252089 -0.21666306 1.667081 -0.7152600 2.165678  
## Jul 2022 0.9212881 -0.02058393 1.863160 -0.5191808 2.361757  
## Aug 2022 0.7320541 -0.20981793 1.673926 -0.7084148 2.172523  
## Sep 2022 0.7281216 -0.21375038 1.669994 -0.7123473 2.168590  
## Oct 2022 0.7980116 -0.14386042 1.739884 -0.6424573 2.238480  
## Nov 2022 0.8124544 -0.12941763 1.754326 -0.6280145 2.252923  
## Dec 2022 0.6979977 -0.24387424 1.639870 -0.7424712 2.138467  
## Jan 2023 0.7288115 -0.21594522 1.673568 -0.7160692 2.173692  
## Feb 2023 0.7250820 -0.21969651 1.669860 -0.7198320 2.169996  
## Mar 2023 0.7370407 -0.20775723 1.681839 -0.7079030 2.181984  
## Apr 2023 0.7523552 -0.19244271 1.697153 -0.6925885 2.197299  
## May 2023 0.7037726 -0.24102525 1.648571 -0.7411710 2.148716  
## Jun 2023 0.7146658 -0.23013207 1.659464 -0.7302779 2.159610  
## Jul 2023 0.8523061 -0.09249177 1.797104 -0.5926376 2.297250  
## Aug 2023 0.7305862 -0.21421167 1.675384 -0.7143575 2.175530  
## Sep 2023 0.7300047 -0.21479320 1.674803 -0.7149390 2.174948  
## Oct 2023 0.7590482 -0.18574969 1.703846 -0.6858955 2.203992  
## Nov 2023 0.8168216 -0.12797629 1.761619 -0.6281221 2.261765  
## Dec 2023 0.7141009 -0.23069695 1.658899 -0.7308427 2.159045  
## Jan 2024 0.7379922 -0.20863794 1.684622 -0.7097537 2.185738  
## Feb 2024 0.7354809 -0.21116302 1.682125 -0.7122860 2.183248  
## Mar 2024 0.7396783 -0.20697798 1.686335 -0.7081075 2.187464  
## Apr 2024 0.7453915 -0.20126480 1.692048 -0.7023944 2.193177  
## May 2024 0.7245193 -0.22213702 1.671176 -0.7232666 2.172305  
## Jun 2024 0.7371625 -0.20949372 1.683819 -0.7106233 2.184948  
## Jul 2024 0.8033032 -0.14335307 1.749959 -0.6444826 2.251089  
## Aug 2024 0.7415000 -0.20515630 1.688156 -0.7062859 2.189286  
## Sep 2024 0.7405711 -0.20608515 1.687227 -0.7072147 2.188357  
## Oct 2024 0.7604933 -0.18616299 1.707150 -0.6872925 2.208279  
## Nov 2024 0.7740580 -0.17259824 1.720714 -0.6737278 2.221844  
## Dec 2024 0.7313665 -0.21528978 1.678023 -0.7164193 2.179152



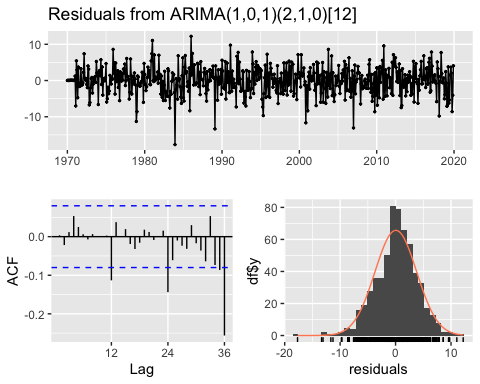


##   
## Ljung-Box test  
##   
## data: Residuals from ARIMA(1,1,0)(0,0,2)[12] with drift  
## Q\* = 77.113, df = 20, p-value = 1.207e-08  
##   
## Model df: 4. Total lags used: 24

## Point Forecast Lo 80 Hi 80 Lo 95 Hi 95  
## Jan 2020 2.063050 -0.7122359 4.838335 -2.181383 6.307483  
## Feb 2020 1.452940 -1.7051479 4.611027 -3.376939 6.282818  
## Mar 2020 1.444109 -2.3410511 5.229269 -4.344794 7.233012  
## Apr 2020 1.273225 -2.9275306 5.473980 -5.151276 7.697725  
## May 2020 1.354154 -3.2741079 5.982416 -5.724162 8.432470  
## Jun 2020 1.319844 -3.6785027 6.318190 -6.324467 8.964155  
## Jul 2020 1.337289 -4.0145479 6.689125 -6.847639 9.522217  
## Aug 2020 1.331084 -4.3484238 7.010591 -7.354973 10.017140  
## Sep 2020 1.335685 -4.6552696 7.326641 -7.826690 10.498061  
## Oct 2020 1.335349 -4.9509134 7.621611 -8.278660 10.949358  
## Nov 2020 1.700845 -4.8677803 8.269471 -8.345001 11.746691  
## Dec 2020 1.412632 -5.4265695 8.251833 -9.047024 11.872287  
## Jan 2021 1.550038 -5.6212982 8.721374 -9.417574 12.517650  
## Feb 2021 1.519647 -5.9366924 8.975985 -9.883840 12.923133  
## Mar 2021 1.473166 -6.2717673 9.218100 -10.371687 13.318020  
## Apr 2021 1.458855 -6.5580437 9.475753 -10.801933 13.719642  
## May 2021 1.467407 -6.8152875 9.750102 -11.199881 14.134695  
## Jun 2021 1.465498 -7.0734999 10.004496 -11.593772 14.524768  
## Jul 2021 1.468297 -7.3200752 10.256670 -11.972358 14.908953  
## Aug 2021 1.468945 -7.5616768 10.499567 -12.342199 15.280089  
## Sep 2021 1.470576 -7.7960720 10.737224 -12.701539 15.642691  
## Oct 2021 1.471758 -8.0250044 10.968520 -13.052286 15.995802  
## Nov 2021 1.551944 -8.1695082 11.273396 -13.315734 16.419621  
## Dec 2021 1.476409 -8.4646463 11.417464 -13.727123 16.679941  
## Jan 2022 1.512887 -8.6543546 11.680129 -14.036567 17.062341  
## Feb 2022 1.498180 -8.8852235 11.881583 -14.381865 17.378224  
## Mar 2022 1.506862 -9.0905708 12.104295 -14.700513 17.714237  
## Apr 2022 1.504856 -9.3013466 12.311059 -15.021805 18.031518  
## May 2022 1.507735 -9.5037387 12.519208 -15.332861 18.348330  
## Jun 2022 1.508381 -9.7043999 12.721162 -15.640088 18.656850  
## Jul 2022 1.510047 -9.9005826 12.920677 -15.941005 18.961100  
## Aug 2022 1.511248 -10.0938173 13.116313 -16.237168 19.259663  
## Sep 2022 1.512661 -10.2836533 13.308975 -16.528245 19.553567  
## Oct 2022 1.513977 -10.4705267 13.498480 -16.814740 19.842693  
## Nov 2022 1.515337 -10.6544496 13.685124 -17.096746 20.127420  
## Dec 2022 1.516677 -10.8356122 13.868967 -17.374519 20.407874  
## Jan 2023 1.518027 -11.0141089 14.050162 -17.648221 20.684274  
## Feb 2023 1.519372 -11.1900647 14.228808 -17.918034 20.956778  
## Mar 2023 1.520719 -11.3635792 14.405017 -18.184115 21.225553  
## Apr 2023 1.522065 -11.5347529 14.578883 -18.446615 21.490745  
## May 2023 1.523412 -11.7036762 14.750500 -18.705674 21.752497  
## Jun 2023 1.524758 -11.8704356 14.919952 -18.961423 22.010939  
## Jul 2023 1.526105 -12.0351111 15.087320 -19.213985 22.266194  
## Aug 2023 1.527451 -12.1977787 15.252681 -19.463476 22.518378  
## Sep 2023 1.528798 -12.3585093 15.416104 -19.710005 22.767600  
## Oct 2023 1.530144 -12.5173700 15.577658 -19.953675 23.013963  
## Nov 2023 1.531490 -12.6744241 15.737405 -20.194581 23.257562  
## Dec 2023 1.532837 -12.8297313 15.895405 -20.432816 23.498489  
## Jan 2024 1.534183 -12.9833482 16.051715 -20.668465 23.736832  
## Feb 2024 1.535530 -13.1353284 16.206388 -20.901612 23.972671  
## Mar 2024 1.536876 -13.2857227 16.359475 -21.132333 24.206085  
## Apr 2024 1.538223 -13.4345793 16.511025 -21.360702 24.437147  
## May 2024 1.539569 -13.5819439 16.661082 -21.586789 24.665928  
## Jun 2024 1.540916 -13.7278602 16.809691 -21.810662 24.892493  
## Jul 2024 1.542262 -13.8723697 16.956894 -22.032383 25.116907  
## Aug 2024 1.543609 -14.0155120 17.102729 -22.252013 25.339230  
## Sep 2024 1.544955 -14.1573248 17.247235 -22.469610 25.559520  
## Oct 2024 1.546301 -14.2978441 17.390447 -22.685228 25.777831  
## Nov 2024 1.547648 -14.4371044 17.532400 -22.898921 25.994217  
## Dec 2024 1.548994 -14.5751387 17.673127 -23.110739 26.208728

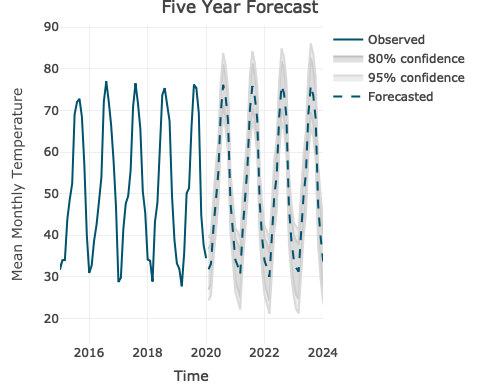


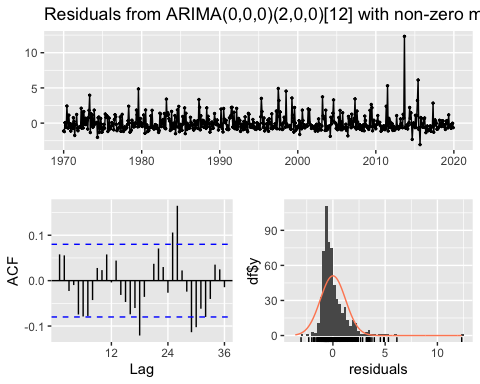
# summary of DEN\_TEMP\_MODEL  
checkresiduals(DEN\_TEMP\_MODEL)



##   
## Ljung-Box test  
##   
## data: Residuals from ARIMA(1,0,1)(2,1,0)[12]  
## Q\* = 26.038, df = 20, p-value = 0.1646  
##   
## Model df: 4. Total lags used: 24

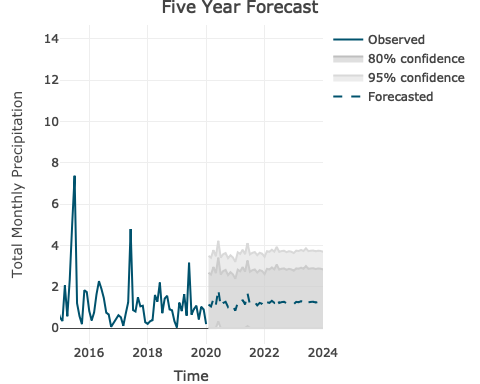
## Point Forecast Lo 80 Hi 80 Lo 95 Hi 95  
## Jan 2020 31.82691 26.95164 36.70218 24.37083 39.28299  
## Feb 2020 33.15217 28.18162 38.12273 25.55037 40.75398  
## Mar 2020 41.67049 36.68617 46.65481 34.04763 49.29335  
## Apr 2020 49.42865 44.44232 54.41499 41.80272 57.05459  
## May 2020 54.91110 49.92448 59.89773 47.28472 62.53749  
## Jun 2020 69.31051 64.32384 74.29718 61.68406 76.93696  
## Jul 2020 76.14849 71.16182 81.13517 68.52203 83.77495  
## Aug 2020 73.34497 68.35829 78.33164 65.71850 80.97143  
## Sep 2020 67.53486 62.54819 72.52154 59.90840 75.16133  
## Oct 2020 47.87197 42.88529 52.85864 40.24550 55.49843  
## Nov 2020 40.71082 35.72415 45.69750 33.08436 48.33728  
## Dec 2020 34.11553 29.12885 39.10220 26.48907 41.74199  
## Jan 2021 32.62560 27.21402 38.03717 24.34930 40.90189  
## Feb 2021 30.50341 25.07574 35.93107 22.20251 38.80431  
## Mar 2021 41.07647 35.64645 46.50648 32.77198 49.38095  
## Apr 2021 48.96324 43.53288 54.39359 40.65822 57.26825  
## May 2021 56.63027 51.19986 62.06068 48.32518 64.93536  
## Jun 2021 70.29181 64.86139 75.72222 61.98671 78.59691  
## Jul 2021 75.86274 70.43233 81.29316 67.55764 84.16785  
## Aug 2021 73.18927 67.75885 78.61968 64.88416 81.49437  
## Sep 2021 67.85254 62.42212 73.28295 59.54743 76.15764  
## Oct 2021 47.86545 42.43503 53.29586 39.56034 56.17055  
## Nov 2021 39.38592 33.95551 44.81634 31.08082 47.69103  
## Dec 2021 33.85799 28.42758 39.28841 25.55289 42.16309  
## Jan 2022 32.22354 26.48031 37.96678 23.44003 41.00706  
## Feb 2022 30.00456 24.24932 35.75979 21.20269 38.80642  
## Mar 2022 39.21333 33.45635 44.97032 30.40879 48.01788  
## Apr 2022 49.48961 43.73238 55.24685 40.68468 58.29455  
## May 2022 54.32003 48.56275 60.07730 45.51503 63.12502  
## Jun 2022 68.49215 62.73487 74.24943 59.68715 77.29715  
## Jul 2022 76.04202 70.28474 81.79930 67.23702 84.84702  
## Aug 2022 74.03600 68.27872 79.79328 65.23100 82.84101  
## Sep 2022 68.33953 62.58225 74.09681 59.53453 77.14453  
## Oct 2022 46.75500 40.99772 52.51228 37.95000 55.56000  
## Nov 2022 38.95992 33.20264 44.71720 30.15492 47.76492  
## Dec 2022 34.14124 28.38396 39.89853 25.33624 42.94625  
## Jan 2023 32.15573 25.64915 38.66231 22.20477 42.10669  
## Feb 2023 31.27172 24.73732 37.80612 21.27822 41.26522  
## Mar 2023 40.49373 33.95528 47.03218 30.49403 50.49343  
## Apr 2023 49.36297 42.82393 55.90202 39.36237 59.36358  
## May 2023 54.99597 48.45683 61.53510 44.99523 64.99670  
## Jun 2023 69.15158 62.61244 75.69072 59.15082 79.15233  
## Jul 2023 76.04613 69.50698 82.58527 66.04537 86.04688  
## Aug 2023 73.61214 67.07299 80.15128 63.61138 83.61289  
## Sep 2023 67.94456 61.40542 74.48371 57.94380 77.94532  
## Oct 2023 47.38911 40.84996 53.92825 37.38835 57.38987  
## Nov 2023 39.69414 33.15500 46.23329 29.69338 49.69490  
## Dec 2023 34.07573 27.53658 40.61487 24.07497 44.07649  
## Jan 2024 32.34357 25.35815 39.32899 21.66029 43.02685  
## Feb 2024 30.73609 23.73364 37.73854 20.02676 41.44541  
## Mar 2024 40.45708 33.45214 47.46201 29.74395 51.17020  
## Apr 2024 49.23959 42.23429 56.24489 38.52591 59.95327  
## May 2024 55.46916 48.46381 62.47451 44.75540 66.18292  
## Jun 2024 69.44460 62.43924 76.44996 58.73083 80.15838  
## Jul 2024 75.97723 68.97187 82.98259 65.26345 86.69101  
## Aug 2024 73.53889 66.53353 80.54426 62.82512 84.25267  
## Sep 2024 67.98844 60.98308 74.99380 57.27466 78.70222  
## Oct 2024 47.44066 40.43529 54.44602 36.72688 58.15443  
## Nov 2024 39.43463 32.42927 46.44000 28.72086 50.14841  
## Dec 2024 34.00784 27.00247 41.01320 23.29406 44.72161

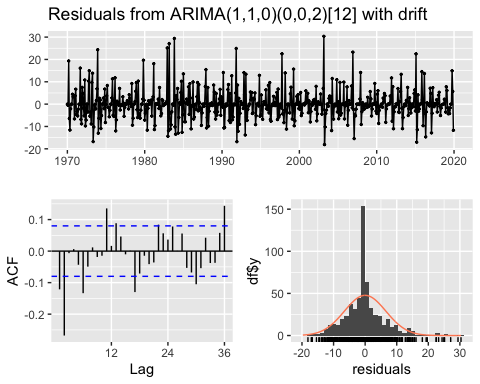




##   
## Ljung-Box test  
##   
## data: Residuals from ARIMA(0,0,0)(2,0,0)[12] with non-zero mean  
## Q\* = 42.773, df = 21, p-value = 0.00336  
##   
## Model df: 3. Total lags used: 24

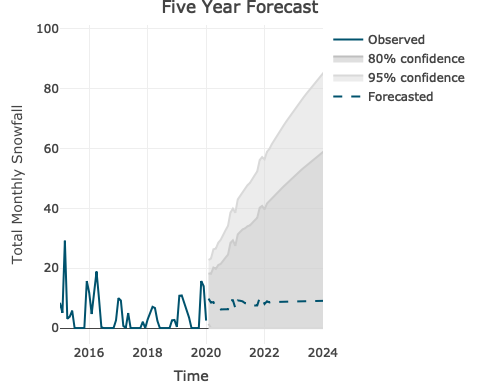
## Point Forecast Lo 80 Hi 80 Lo 95 Hi 95  
## Jan 2020 1.1359421 -0.40626668 2.678151 -1.2226627 3.494547  
## Feb 2020 1.0438854 -0.49832332 2.586094 -1.3147193 3.402490  
## Mar 2020 1.4111801 -0.13102866 2.953389 -0.9474247 3.769785  
## Apr 2020 1.1156624 -0.42654638 2.657871 -1.2429424 3.474267  
## May 2020 1.8614514 0.31924268 3.403660 -0.4971533 4.220056  
## Jun 2020 1.0500217 -0.49218709 2.592230 -1.3085831 3.408626  
## Jul 2020 1.2137431 -0.32846566 2.755952 -1.1448617 3.572348  
## Aug 2020 1.2704160 -0.27179275 2.812625 -1.0881888 3.629021  
## Sep 2020 1.0194670 -0.52274177 2.561676 -1.3391378 3.378072  
## Oct 2020 1.1612018 -0.38100699 2.703411 -1.1974030 3.519807  
## Nov 2020 1.0562629 -0.48594585 2.598472 -1.3023418 3.414868  
## Dec 2020 0.8431998 -0.69900892 2.385409 -1.5154049 3.201805  
## Jan 2021 1.2381280 -0.34839867 2.824655 -1.1882552 3.664511  
## Feb 2021 1.1590035 -0.42752317 2.745530 -1.2673797 3.585387  
## Mar 2021 1.3614820 -0.22504465 2.948009 -1.0649011 3.787865  
## Apr 2021 1.1458039 -0.44072271 2.732331 -1.2805792 3.572187  
## May 2021 1.6811371 0.09461041 3.267664 -0.7452461 4.107520  
## Jun 2021 1.1368936 -0.44963311 2.723420 -1.2894896 3.563277  
## Jul 2021 1.2138933 -0.37263332 2.800420 -1.2124898 3.640276  
## Aug 2021 1.2497809 -0.33674573 2.836308 -1.1766022 3.676164  
## Sep 2021 1.0975981 -0.48892857 2.684125 -1.3287850 3.523981  
## Oct 2021 1.2164722 -0.37005442 2.802999 -1.2099109 3.642855  
## Nov 2021 1.1730940 -0.41343271 2.759621 -1.2532892 3.599477  
## Dec 2021 1.0231201 -0.56340659 2.609647 -1.4032631 3.449503  
## Jan 2022 1.2497482 -0.36562751 2.865124 -1.2207558 3.720252  
## Feb 2022 1.2178684 -0.39750733 2.833244 -1.2526356 3.688372  
## Mar 2022 1.3177281 -0.29764762 2.933104 -1.1527759 3.788232  
## Apr 2022 1.2246421 -0.39073363 2.840018 -1.2458619 3.695146  
## May 2022 1.4573953 -0.15798041 3.072771 -1.0131087 3.927899  
## Jun 2022 1.2133815 -0.40199427 2.828757 -1.2571225 3.683885  
## Jul 2022 1.2546935 -0.36068228 2.870069 -1.2158105 3.725197  
## Aug 2022 1.2712233 -0.34415243 2.886599 -1.1992807 3.741727  
## Sep 2022 1.1996533 -0.41572243 2.815029 -1.2708507 3.670157  
## Oct 2022 1.2480248 -0.36735096 2.863401 -1.2224792 3.718529  
## Nov 2022 1.2229882 -0.39238749 2.838364 -1.2475158 3.693492  
## Dec 2022 1.1572092 -0.45816656 2.772585 -1.3132948 3.627713  
## Jan 2023 1.2667347 -0.35347473 2.886944 -1.2111618 3.744631  
## Feb 2023 1.2480568 -0.37215259 2.868266 -1.2298396 3.725953  
## Mar 2023 1.3002669 -0.31994255 2.920476 -1.1776296 3.778163  
## Apr 2023 1.2478606 -0.37234881 2.868070 -1.2300359 3.725757  
## May 2023 1.3783495 -0.24185988 2.998559 -1.0995469 3.856246  
## Jun 2023 1.2439052 -0.37630425 2.864115 -1.2339913 3.721802  
## Jul 2023 1.2645656 -0.35564383 2.884775 -1.2133309 3.742462  
## Aug 2023 1.2735370 -0.34667241 2.893746 -1.2043595 3.751433  
## Sep 2023 1.2351373 -0.38507212 2.855347 -1.2427592 3.713034  
## Oct 2023 1.2633133 -0.35689611 2.883523 -1.2145832 3.741210  
## Nov 2023 1.2512484 -0.36896100 2.871458 -1.2266481 3.729145  
## Dec 2023 1.2145535 -0.40565593 2.834763 -1.2633430 3.692450  
## Jan 2024 1.2724487 -0.34937634 2.894274 -1.2079186 3.752816  
## Feb 2024 1.2635148 -0.35831023 2.885340 -1.2168525 3.743882  
## Mar 2024 1.2899789 -0.33184610 2.911804 -1.1903884 3.770346  
## Apr 2024 1.2644074 -0.35741760 2.886232 -1.2159599 3.744775  
## May 2024 1.3282143 -0.29361074 2.950039 -1.1521530 3.808582  
## Jun 2024 1.2618897 -0.35993533 2.883715 -1.2184776 3.742257  
## Jul 2024 1.2726112 -0.34921381 2.894436 -1.2077561 3.752979  
## Aug 2024 1.2770713 -0.34475373 2.898896 -1.2032960 3.757439  
## Sep 2024 1.2578676 -0.36395745 2.879693 -1.2224998 3.738235  
## Oct 2024 1.2713834 -0.35044161 2.893208 -1.2089839 3.751751  
## Nov 2024 1.2649959 -0.35682912 2.886821 -1.2153714 3.745363  
## Dec 2024 1.2470074 -0.37481759 2.868832 -1.2333599 3.727375

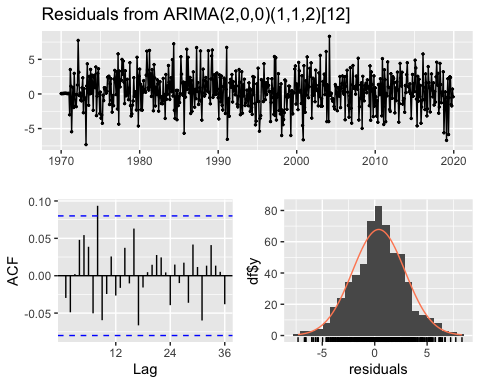




##   
## Ljung-Box test  
##   
## data: Residuals from ARIMA(1,1,0)(0,0,2)[12] with drift  
## Q\* = 106.59, df = 20, p-value = 8.171e-14  
##   
## Model df: 4. Total lags used: 24

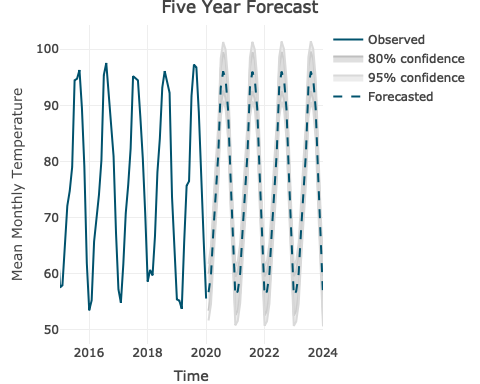
## Point Forecast Lo 80 Hi 80 Lo 95 Hi 95  
## Jan 2020 9.838534 1.385993 18.29107 -3.088512 22.76558  
## Feb 2020 8.503163 -1.118575 18.12490 -6.212015 23.21834  
## Mar 2020 8.684698 -2.846665 20.21606 -8.951000 26.32040  
## Apr 2020 6.989634 -5.809324 19.78859 -12.584683 26.56395  
## May 2020 6.972019 -7.129484 21.07352 -14.594369 28.53841  
## Jun 2020 6.202478 -9.027208 21.43216 -17.089317 29.49427  
## Jul 2020 6.262239 -10.044692 22.56917 -18.677060 31.20154  
## Aug 2020 6.254944 -11.050692 23.56058 -20.211743 32.72163  
## Sep 2020 6.278235 -11.976569 24.53304 -21.640079 34.19655  
## Oct 2020 9.315649 -9.839163 28.47046 -19.979108 38.61041  
## Nov 2020 9.308847 -10.706498 29.32419 -21.301981 39.91967  
## Dec 2020 6.653179 -14.186777 27.49314 -25.218783 38.52514  
## Jan 2021 9.227955 -12.853860 31.30977 -24.543267 42.99918  
## Feb 2021 9.124034 -13.928242 32.17631 -26.131380 44.37945  
## Mar 2021 8.923805 -15.147483 32.99509 -27.890053 45.73766  
## Apr 2021 8.300607 -16.709352 33.31057 -29.948824 46.55004  
## May 2021 8.105738 -17.825959 34.03744 -31.553370 47.76485  
## Jun 2021 7.496317 -19.317926 34.31056 -33.512529 48.50516  
## Jul 2021 7.520607 -20.151372 35.19259 -34.800034 49.84125  
## Aug 2021 7.533025 -20.969419 36.03547 -36.057701 51.12375  
## Sep 2021 7.550857 -21.759182 36.86090 -37.274979 52.37669  
## Oct 2021 10.131031 -19.964651 40.22671 -35.896342 56.15840  
## Nov 2021 9.954724 -20.906736 40.81618 -37.243806 57.15325  
## Dec 2021 8.051414 -23.557218 39.66005 -40.289818 56.39265  
## Jan 2022 8.946510 -23.728931 41.62195 -41.026264 58.91928  
## Feb 2022 8.565140 -24.987078 42.11736 -42.748550 59.87883  
## Mar 2022 8.766018 -25.708680 43.24072 -43.958483 61.49052  
## Apr 2022 8.701309 -26.641271 44.04389 -45.350503 62.75312  
## May 2022 8.757745 -27.445457 44.96095 -46.610275 64.12576  
## Jun 2022 8.758922 -28.278861 45.79670 -47.885480 65.40332  
## Jul 2022 8.785304 -29.071362 46.64197 -49.111471 66.68208  
## Aug 2022 8.800190 -29.856813 47.45719 -50.320594 67.92097  
## Sep 2022 8.820319 -30.621320 48.26196 -51.500463 69.14110  
## Oct 2022 8.838057 -31.372672 49.04879 -52.658946 70.33506  
## Nov 2022 8.856886 -32.108603 49.82237 -53.794423 71.50819  
## Dec 2022 8.875217 -32.831327 50.58176 -54.909438 72.65987  
## Jan 2023 8.893775 -33.540907 51.32846 -56.004470 73.79202  
## Feb 2023 8.912229 -34.238295 52.06275 -57.080803 74.90526  
## Mar 2023 8.930731 -34.923957 52.78542 -58.139227 76.00069  
## Apr 2023 8.949211 -35.598510 53.49693 -59.180649 77.07907  
## May 2023 8.967701 -36.262436 54.19784 -60.205824 78.14123  
## Jun 2023 8.986187 -36.916221 54.88859 -61.215489 79.18786  
## Jul 2023 9.004674 -37.560301 55.56965 -62.210309 80.21966  
## Aug 2023 9.023161 -38.195085 56.24141 -63.190914 81.23724  
## Sep 2023 9.041648 -38.820952 56.90425 -64.157883 82.24118  
## Oct 2023 9.060135 -39.438260 57.55853 -65.111760 83.23203  
## Nov 2023 9.078622 -40.047340 58.20458 -66.053053 84.21030  
## Dec 2023 9.097109 -40.648504 58.84272 -66.982240 85.17646  
## Jan 2024 9.115596 -41.242043 59.47323 -67.899766 86.13096  
## Feb 2024 9.134083 -41.828233 60.09640 -68.806053 87.07422  
## Mar 2024 9.152569 -42.407331 60.71247 -69.701494 88.00663  
## Apr 2024 9.171056 -42.979583 61.32170 -70.586464 88.92858  
## May 2024 9.189543 -43.545217 61.92430 -71.461314 89.84040  
## Jun 2024 9.208030 -44.104452 62.52051 -72.326376 90.74244  
## Jul 2024 9.226517 -44.657494 63.11053 -73.181966 91.63500  
## Aug 2024 9.245004 -45.204536 63.69454 -74.028382 92.51839  
## Sep 2024 9.263491 -45.745765 64.27275 -74.865906 93.39289  
## Oct 2024 9.281978 -46.281356 64.84531 -75.694808 94.25876  
## Nov 2024 9.300465 -46.811476 65.41241 -76.515343 95.11627  
## Dec 2024 9.318952 -47.336283 65.97419 -77.327753 95.96566

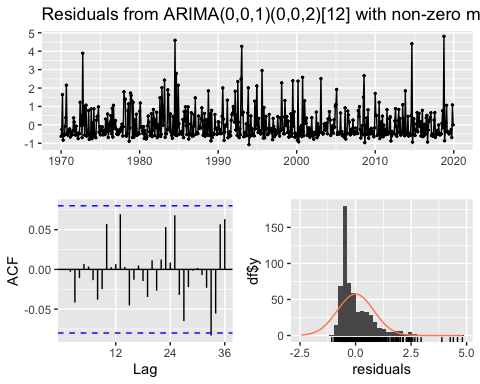




##   
## Ljung-Box test  
##   
## data: Residuals from ARIMA(2,0,0)(1,1,2)[12]  
## Q\* = 24.751, df = 19, p-value = 0.1689  
##   
## Model df: 5. Total lags used: 24

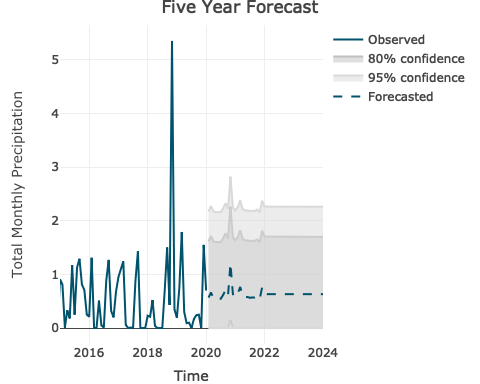
## Point Forecast Lo 80 Hi 80 Lo 95 Hi 95  
## Jan 2020 56.71298 53.41694 60.00903 51.67212 61.75384  
## Feb 2020 59.74680 56.36750 63.12610 54.57861 64.91499  
## Mar 2020 67.71118 64.29117 71.13120 62.48072 72.94165  
## Apr 2020 74.83381 71.40795 78.25966 69.59441 80.07320  
## May 2020 81.30066 77.87328 84.72804 76.05894 86.54239  
## Jun 2020 93.15165 89.72397 96.57932 87.90947 98.39382  
## Jul 2020 96.04372 92.61598 99.47146 90.80144 101.28599  
## Aug 2020 94.70681 91.27905 98.13456 89.46451 99.94910  
## Sep 2020 89.33282 85.90506 92.76058 84.09052 94.57512  
## Oct 2020 77.60740 74.17964 81.03515 72.36509 82.84970  
## Nov 2020 65.93774 62.50998 69.36549 60.69543 71.18004  
## Dec 2020 56.06266 52.63491 59.49042 50.82036 61.30497  
## Jan 2021 56.90188 53.42667 60.37710 51.58700 62.21677  
## Feb 2021 60.07303 56.59540 63.55066 54.75445 65.39160  
## Mar 2021 67.80516 64.32633 71.28399 62.48475 73.12557  
## Apr 2021 74.84004 71.36103 78.31904 69.51936 80.16071  
## May 2021 81.54365 78.06460 85.02270 76.22291 86.86440  
## Jun 2021 93.21523 89.73617 96.69428 87.89447 98.53598  
## Jul 2021 95.99666 92.51760 99.47572 90.67590 101.31742  
## Aug 2021 94.60983 91.13077 98.08889 89.28907 99.93060  
## Sep 2021 89.38960 85.91054 92.86866 84.06884 94.71036  
## Oct 2021 77.62767 74.14861 81.10673 72.30691 82.94843  
## Nov 2021 65.89716 62.41810 69.37622 60.57640 71.21793  
## Dec 2021 56.07145 52.59239 59.55051 50.75069 61.39221  
## Jan 2022 56.88136 53.37355 60.38917 51.51663 62.24609  
## Feb 2022 60.02100 56.51173 63.53027 54.65403 65.38797  
## Mar 2022 67.79123 64.28123 71.30123 62.42314 73.15932  
## Apr 2022 74.84178 71.33167 78.35189 69.47354 80.21003  
## May 2022 81.49416 77.98403 85.00430 76.12587 86.86245  
## Jun 2022 93.20256 89.69242 96.71270 87.83426 98.57086  
## Jul 2022 96.00678 92.49664 99.51692 90.63848 101.37508  
## Aug 2022 94.63024 91.12010 98.14038 89.26194 99.99854  
## Sep 2022 89.37779 85.86765 92.88793 84.00949 94.74609  
## Oct 2022 77.62346 74.11332 81.13360 72.25516 82.99176  
## Nov 2022 65.90566 62.39552 69.41580 60.53736 71.27396  
## Dec 2022 56.06962 52.55948 59.57976 50.70132 61.43792  
## Jan 2023 56.88565 53.34364 60.42767 51.46861 62.30270  
## Feb 2023 60.03188 56.48824 63.57552 54.61235 65.45140  
## Mar 2023 67.79414 64.24970 71.33859 62.37338 73.21491  
## Apr 2023 74.84142 71.29685 78.38598 69.42048 80.26236  
## May 2023 81.50451 77.95992 85.04910 76.08352 86.92550  
## Jun 2023 93.20521 89.66061 96.74981 87.78421 98.62620  
## Jul 2023 96.00466 92.46006 99.54926 90.58366 101.42566  
## Aug 2023 94.62597 91.08137 98.17057 89.20497 100.04697  
## Sep 2023 89.38026 85.83566 92.92486 83.95926 94.80126  
## Oct 2023 77.62434 74.07974 81.16894 72.20334 83.04534  
## Nov 2023 65.90388 62.35928 69.44848 60.48288 71.32488  
## Dec 2023 56.07000 52.52540 59.61460 50.64900 61.49100  
## Jan 2024 56.88475 53.30930 60.46021 51.41657 62.35294  
## Feb 2024 60.02960 56.45258 63.60663 54.55902 65.50019  
## Mar 2024 67.79353 64.21573 71.37134 62.32175 73.26532  
## Apr 2024 74.84149 71.26357 78.41941 69.36954 80.31345  
## May 2024 81.50235 77.92440 85.08029 76.03035 86.97435  
## Jun 2024 93.20465 89.62670 96.78261 87.73265 98.67666  
## Jul 2024 96.00511 92.42715 99.58306 90.53310 101.47712  
## Aug 2024 94.62687 91.04891 98.20482 89.15485 100.09888  
## Sep 2024 89.37974 85.80179 92.95770 83.90773 94.85175  
## Oct 2024 77.62415 74.04620 81.20211 72.15214 83.09616  
## Nov 2024 65.90425 62.32630 69.48221 60.43224 71.37626  
## Dec 2024 56.06992 52.49197 59.64788 50.59791 61.54193



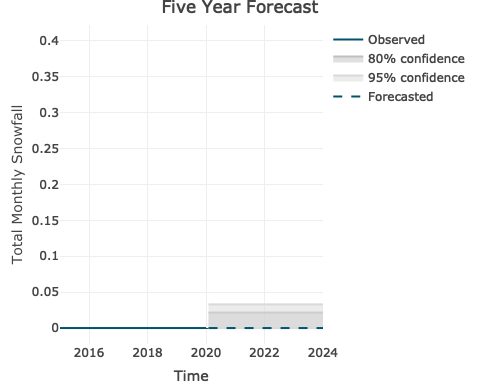


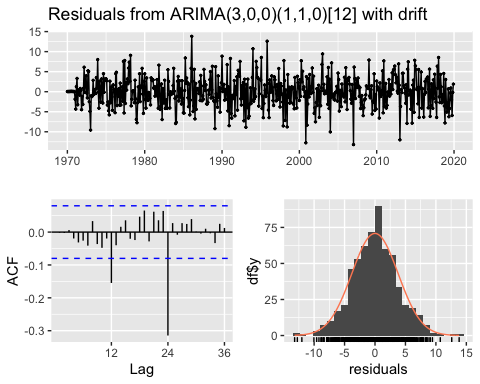
##   
## Ljung-Box test  
##   
## data: Residuals from ARIMA(0,0,1)(0,0,2)[12] with non-zero mean  
## Q\* = 12.251, df = 20, p-value = 0.9071  
##   
## Model df: 4. Total lags used: 24

## Point Forecast Lo 80 Hi 80 Lo 95 Hi 95  
## Jan 2020 0.5676346 -0.4801555 1.615425 -1.0348221 2.170091  
## Feb 2020 0.6603943 -0.3950658 1.715854 -0.9537927 2.274581  
## Mar 2020 0.5615109 -0.4939492 1.616971 -1.0526760 2.175698  
## Apr 2020 0.5401619 -0.5152982 1.595622 -1.0740250 2.154349  
## May 2020 0.5490427 -0.5064174 1.604503 -1.0651442 2.163230  
## Jun 2020 0.5447982 -0.5106619 1.600258 -1.0693887 2.158985  
## Jul 2020 0.6173797 -0.4380804 1.672840 -0.9968072 2.231567  
## Aug 2020 0.7110865 -0.3443736 1.766547 -0.9031004 2.325273  
## Sep 2020 0.6121087 -0.4433514 1.667569 -1.0020782 2.226296  
## Oct 2020 1.2066812 0.1512211 2.262141 -0.4075057 2.820868  
## Nov 2020 0.6311265 -0.4243336 1.686587 -0.9830604 2.245313  
## Dec 2020 0.5777185 -0.4777416 1.633179 -1.0364685 2.191905  
## Jan 2021 0.6407479 -0.4153372 1.696833 -0.9743949 2.255891  
## Feb 2021 0.7660887 -0.2900056 1.822183 -0.8490682 2.381246  
## Mar 2021 0.6001411 -0.4559532 1.656235 -1.0150158 2.215298  
## Apr 2021 0.5755943 -0.4805000 1.631689 -1.0395625 2.190751  
## May 2021 0.5780891 -0.4780052 1.634183 -1.0370677 2.193246  
## Jun 2021 0.5639164 -0.4921779 1.620011 -1.0512404 2.179073  
## Jul 2021 0.5706114 -0.4854829 1.626706 -1.0445455 2.185768  
## Aug 2021 0.5683244 -0.4877699 1.624419 -1.0468325 2.183481  
## Sep 2021 0.5935596 -0.4625347 1.649654 -1.0215973 2.208716  
## Oct 2021 0.5417369 -0.5143575 1.597831 -1.0734200 2.156894  
## Nov 2021 0.7567546 -0.2993397 1.812849 -0.8584023 2.371911  
## Dec 2021 0.6479282 -0.4081662 1.704022 -0.9672287 2.263085  
## Jan 2022 0.6316270 -0.4325929 1.695847 -0.9959569 2.259211  
## Feb 2022 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Mar 2022 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Apr 2022 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## May 2022 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Jun 2022 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Jul 2022 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Aug 2022 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Sep 2022 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Oct 2022 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Nov 2022 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Dec 2022 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Jan 2023 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Feb 2023 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Mar 2023 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Apr 2023 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## May 2023 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Jun 2023 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Jul 2023 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Aug 2023 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Sep 2023 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Oct 2023 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Nov 2023 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Dec 2023 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Jan 2024 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Feb 2024 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Mar 2024 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Apr 2024 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## May 2024 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Jun 2024 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Jul 2024 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Aug 2024 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Sep 2024 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Oct 2024 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Nov 2024 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411  
## Dec 2024 0.6316450 -0.4326939 1.695984 -0.9961209 2.259411



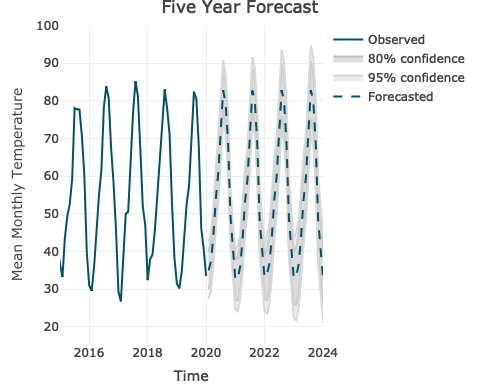
## Point Forecast Lo 80 Hi 80 Lo 95 Hi 95  
## Jan 2020 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Feb 2020 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Mar 2020 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Apr 2020 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## May 2020 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Jun 2020 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Jul 2020 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Aug 2020 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Sep 2020 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Oct 2020 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Nov 2020 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Dec 2020 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Jan 2021 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Feb 2021 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Mar 2021 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Apr 2021 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## May 2021 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Jun 2021 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Jul 2021 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Aug 2021 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Sep 2021 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Oct 2021 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Nov 2021 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Dec 2021 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Jan 2022 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Feb 2022 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Mar 2022 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Apr 2022 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## May 2022 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Jun 2022 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Jul 2022 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Aug 2022 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Sep 2022 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Oct 2022 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Nov 2022 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Dec 2022 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Jan 2023 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Feb 2023 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Mar 2023 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Apr 2023 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## May 2023 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Jun 2023 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Jul 2023 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Aug 2023 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Sep 2023 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Oct 2023 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Nov 2023 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Dec 2023 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Jan 2024 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Feb 2024 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Mar 2024 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Apr 2024 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## May 2024 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Jun 2024 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Jul 2024 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Aug 2024 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Sep 2024 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Oct 2024 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Nov 2024 0 -0.02157173 0.02157173 -0.03299111 0.03299111  
## Dec 2024 0 -0.02157173 0.02157173 -0.03299111 0.03299111

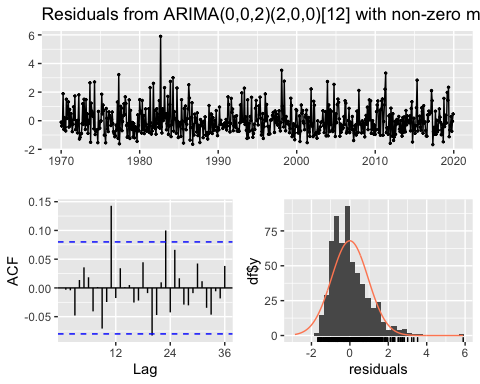




##   
## Ljung-Box test  
##   
## data: Residuals from ARIMA(3,0,0)(1,1,0)[12] with drift  
## Q\* = 95.131, df = 19, p-value = 4.037e-12  
##   
## Model df: 5. Total lags used: 24

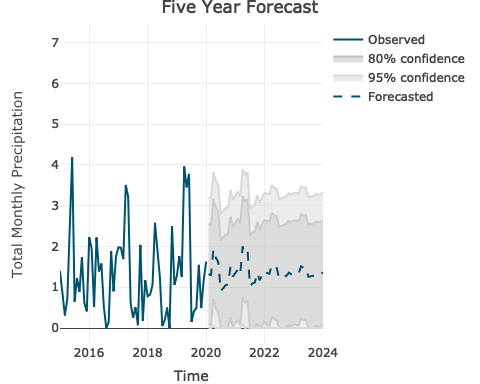
## Point Forecast Lo 80 Hi 80 Lo 95 Hi 95  
## Jan 2020 34.96534 30.02330 39.90738 27.40715 42.52354  
## Feb 2020 37.32782 32.20196 42.45369 29.48849 45.16716  
## Mar 2020 44.28995 39.14981 49.43010 36.42878 52.15113  
## Apr 2020 54.03676 48.88914 59.18438 46.16416 61.90937  
## May 2020 60.77356 55.62273 65.92438 52.89605 68.65106  
## Jun 2020 73.20763 68.05618 78.35908 65.32917 81.08610  
## Jul 2020 82.77576 77.62431 87.92721 74.89730 90.65423  
## Aug 2020 79.27971 74.12824 84.43118 71.40121 87.15820  
## Sep 2020 69.47144 64.31996 74.62292 61.59293 77.34995  
## Oct 2020 49.40712 44.25564 54.55860 41.52861 57.28563  
## Nov 2020 39.54610 34.39462 44.69758 31.66759 47.42461  
## Dec 2020 32.55945 27.40797 37.71093 24.68094 40.43796  
## Jan 2021 32.73224 26.99639 38.46809 23.96002 41.50446  
## Feb 2021 36.08309 30.30536 41.86081 27.24682 44.91935  
## Mar 2021 43.50875 37.72772 49.28978 34.66743 52.35007  
## Apr 2021 53.38792 47.60516 59.17068 44.54395 62.23189  
## May 2021 59.23450 53.45100 65.01801 50.38940 68.07961  
## Jun 2021 72.13247 66.34882 77.91612 63.28714 80.97780  
## Jul 2021 82.67261 76.88896 88.45626 73.82728 91.51794  
## Aug 2021 79.94049 74.15684 85.72415 71.09516 88.78583  
## Sep 2021 68.72403 62.94037 74.50768 59.87869 77.56936  
## Oct 2021 47.90532 42.12167 53.68898 39.05998 56.75066  
## Nov 2021 40.18175 34.39810 45.96541 31.33642 49.02709  
## Dec 2021 33.08330 27.29964 38.86695 24.23796 41.92864  
## Jan 2022 33.91251 27.04291 40.78210 23.40637 44.41865  
## Feb 2022 36.77953 29.83456 43.72449 26.15811 47.40094  
## Mar 2022 43.97828 37.02738 50.92918 33.34779 54.60877  
## Apr 2022 53.79266 46.83864 60.74667 43.15741 64.42790  
## May 2022 60.07502 53.11967 67.03037 49.43773 70.71231  
## Jun 2022 72.74590 65.79029 79.70151 62.10821 83.38359  
## Jul 2022 82.81022 75.85461 89.76583 72.17253 93.44791  
## Aug 2022 79.70414 72.74852 86.65976 69.06644 90.34184  
## Sep 2022 69.17702 62.22139 76.13264 58.53931 79.81472  
## Oct 2022 48.72760 41.77198 55.68322 38.08989 59.36531  
## Nov 2022 39.95770 33.00207 46.91332 29.31999 50.59541  
## Dec 2022 32.91398 25.95835 39.86960 22.27627 43.55168  
## Jan 2023 33.42185 25.79566 41.04804 21.75860 45.08511  
## Feb 2023 36.52571 28.85109 44.20033 24.78840 48.26303  
## Mar 2023 43.83555 36.15710 51.51399 32.09238 55.57871  
## Apr 2023 53.68164 46.00119 61.36209 41.93541 65.42787  
## May 2023 59.75068 52.06937 67.43199 48.00313 71.49823  
## Jun 2023 72.53272 64.85125 80.21420 60.78492 84.28053  
## Jul 2023 82.82997 75.14849 90.51145 71.08216 94.57777  
## Aug 2023 79.90695 72.22547 87.58843 68.15914 91.65476  
## Sep 2023 69.04238 61.36089 76.72386 57.29456 80.79020  
## Oct 2023 48.41219 40.73070 56.09367 36.66437 60.16001  
## Nov 2023 40.15449 32.47301 47.83598 28.40667 51.90231  
## Dec 2023 33.08398 25.40249 40.76546 21.33616 44.83179  
## Jan 2024 33.74915 25.34445 42.15386 20.89527 46.60304  
## Feb 2024 36.73707 28.28008 45.19406 23.80322 49.67092  
## Mar 2024 43.99253 35.53141 52.45365 31.05237 56.93269  
## Apr 2024 53.82310 45.35982 62.28638 40.87963 66.76657  
## May 2024 59.99656 51.53235 68.46077 47.05167 72.94145  
## Jun 2024 72.72419 64.25980 81.18858 59.77902 85.66936  
## Jul 2024 82.90741 74.44302 91.37180 69.96224 95.85258  
## Aug 2024 79.89478 71.43038 88.35918 66.94960 92.83996  
## Sep 2024 69.19540 60.73100 77.65980 56.25022 82.14058  
## Oct 2024 48.65370 40.18930 57.11810 35.70852 61.59889  
## Nov 2024 40.14527 31.68087 48.60967 27.20009 53.09045  
## Dec 2024 33.08787 24.62347 41.55227 20.14269 46.03305

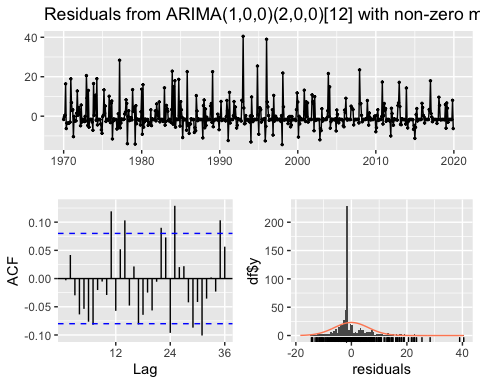




##   
## Ljung-Box test  
##   
## data: Residuals from ARIMA(0,0,2)(2,0,0)[12] with non-zero mean  
## Q\* = 35.485, df = 19, p-value = 0.0122  
##   
## Model df: 5. Total lags used: 24

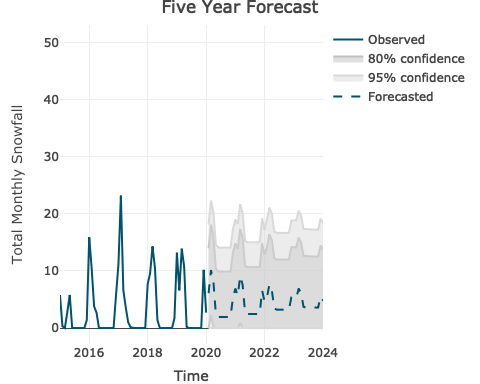
## Point Forecast Lo 80 Hi 80 Lo 95 Hi 95  
## Jan 2020 1.3207779 0.095692302 2.545863 -0.55282884 3.194385  
## Feb 2020 1.3006836 0.069581710 2.531786 -0.58212429 3.183492  
## Mar 2020 1.9325774 0.698948731 3.166206 0.04590516 3.819250  
## Apr 2020 1.7222880 0.488659348 2.955917 -0.16438422 3.608960  
## May 2020 1.6172792 0.383650521 2.850908 -0.26939305 3.503951  
## Jun 2020 0.9123293 -0.321299406 2.145958 -0.97434298 2.799001  
## Jul 2020 0.9746879 -0.258940796 2.208317 -0.91198437 2.861360  
## Aug 2020 1.0532638 -0.180364838 2.286892 -0.83340841 2.939936  
## Sep 2020 1.0692557 -0.164372950 2.302884 -0.81741652 2.955928  
## Oct 2020 1.4982512 0.264622488 2.731880 -0.38842108 3.384923  
## Nov 2020 1.2594851 0.025856452 2.493114 -0.62718712 3.146157  
## Dec 2020 1.3636505 0.130021860 2.597279 -0.52302171 3.250323  
## Jan 2021 1.4333295 0.190966923 2.675692 -0.46670012 3.333359  
## Feb 2021 1.3196707 0.077222358 2.562119 -0.58049005 3.219831  
## Mar 2021 1.9962539 0.753769468 3.238738 0.09603795 3.896470  
## Apr 2021 1.8575397 0.615055293 3.100024 -0.04267623 3.757756  
## May 2021 1.9183577 0.675873307 3.160842 0.01814179 3.818574  
## Jun 2021 1.0260860 -0.216398431 2.268570 -0.87412995 2.926302  
## Jul 2021 1.0914196 -0.151064767 2.333904 -0.80879629 2.991636  
## Aug 2021 1.1186511 -0.123833289 2.361136 -0.78156481 3.018867  
## Sep 2021 1.3564140 0.113929604 2.598898 -0.54380192 3.256630  
## Oct 2021 1.1720659 -0.070418556 2.414550 -0.72815008 3.072282  
## Nov 2021 1.2947009 0.052216489 2.537185 -0.60551503 3.194917  
## Dec 2021 1.4095516 0.167067228 2.652036 -0.49066429 3.309768  
## Jan 2022 1.3491157 0.073185263 2.625046 -0.60225152 3.300483  
## Feb 2022 1.3310017 0.054746249 2.607257 -0.62086255 3.282866  
## Mar 2022 1.5528087 0.276416382 2.829201 -0.39926490 3.504882  
## Apr 2022 1.4893699 0.212977559 2.765762 -0.46270372 3.441443  
## May 2022 1.4733065 0.196914143 2.749699 -0.47876714 3.425380  
## Jun 2022 1.2093544 -0.067037949 2.485747 -0.74271923 3.161428  
## Jul 2022 1.2310712 -0.045321127 2.507464 -0.72100241 3.183145  
## Aug 2022 1.2518226 -0.024569703 2.528215 -0.70025099 3.203896  
## Sep 2022 1.2839209 0.007528623 2.560313 -0.66815266 3.235995  
## Oct 2022 1.3572412 0.080848877 2.633634 -0.59483241 3.309315  
## Nov 2022 1.3188380 0.042445632 2.595230 -0.63323565 3.270912  
## Dec 2022 1.3558004 0.079408059 2.632193 -0.59627322 3.307874  
## Jan 2023 1.3640490 0.085870123 2.642228 -0.59075690 3.318855  
## Feb 2023 1.3365863 0.058389817 2.614783 -0.61824652 3.291419  
## Mar 2023 1.5137467 0.235542837 2.791951 -0.44109742 3.468591  
## Apr 2023 1.4752687 0.197064836 2.753473 -0.47957542 3.430113  
## May 2023 1.4868721 0.208668262 2.765076 -0.46797199 3.441716  
## Jun 2023 1.2566634 -0.021540438 2.534867 -0.69818069 3.211508  
## Jul 2023 1.2738066 -0.004397300 2.552010 -0.68103755 3.228651  
## Aug 2023 1.2823563 0.004152460 2.560560 -0.67248779 3.237200  
## Sep 2023 1.3391100 0.060906169 2.617314 -0.61573409 3.293954  
## Oct 2023 1.3068948 0.028690980 2.585099 -0.64794927 3.261739  
## Nov 2023 1.3295706 0.051366708 2.607774 -0.62527355 3.284415  
## Dec 2023 1.3595610 0.081357111 2.637765 -0.59528314 3.314405  
## Jan 2024 1.3471045 0.066835823 2.627373 -0.61089748 3.305106  
## Feb 2024 1.3397777 0.059488715 2.620067 -0.61825534 3.297811  
## Mar 2024 1.4103941 0.130096541 2.690692 -0.54765204 3.368440  
## Apr 2024 1.3916606 0.111363039 2.671958 -0.56638555 3.349707  
## May 2024 1.3894794 0.109181866 2.669777 -0.56856672 3.347526  
## Jun 2024 1.3031183 0.022820745 2.583416 -0.65492784 3.261164  
## Jul 2024 1.3100080 0.029710403 2.590306 -0.64803818 3.268054  
## Aug 2024 1.3156513 0.035353747 2.595949 -0.64239484 3.273697  
## Sep 2024 1.3296055 0.049307939 2.609903 -0.62844065 3.287652  
## Oct 2024 1.3420518 0.061754231 2.622349 -0.61599435 3.300098  
## Nov 2024 1.3362292 0.055931669 2.616527 -0.62181692 3.294275  
## Dec 2024 1.3480531 0.067755518 2.628351 -0.60999307 3.306099





##   
## Ljung-Box test  
##   
## data: Residuals from ARIMA(1,0,0)(2,0,0)[12] with non-zero mean  
## Q\* = 58.075, df = 20, p-value = 1.408e-05  
##   
## Model df: 4. Total lags used: 24

## Point Forecast Lo 80 Hi 80 Lo 95 Hi 95  
## Jan 2020 6.097223 -1.7773752 13.971821 -5.945936 18.14038  
## Feb 2020 10.155847 2.2136003 18.098093 -1.990771 22.30246  
## Mar 2020 8.159159 0.2157501 16.102568 -3.989236 20.30755  
## Apr 2020 2.441105 -5.5023240 10.384534 -9.707321 14.58953  
## May 2020 1.939713 -6.0037157 9.883143 -10.208713 14.08814  
## Jun 2020 1.939891 -6.0035376 9.883321 -10.208535 14.08832  
## Jul 2020 1.939915 -6.0035143 9.883344 -10.208512 14.08834  
## Aug 2020 1.939918 -6.0035112 9.883347 -10.208509 14.08834  
## Sep 2020 1.939918 -6.0035108 9.883348 -10.208508 14.08834  
## Oct 2020 1.939918 -6.0035107 9.883348 -10.208508 14.08834  
## Nov 2020 5.213411 -2.7300179 13.156840 -6.935015 17.36184  
## Dec 2020 6.897882 -1.0455468 14.841311 -5.250544 19.04631  
## Jan 2021 5.688534 -2.5293418 13.906410 -6.879622 18.25669  
## Feb 2021 9.116560 0.8940287 17.339091 -3.458716 21.69184  
## Mar 2021 7.555676 -0.6669351 15.778288 -5.019723 20.13108  
## Apr 2021 2.656966 -5.5656469 10.879579 -9.918435 15.23237  
## May 2021 2.458690 -5.7639225 10.681303 -10.116711 15.03409  
## Jun 2021 2.458738 -5.7638749 10.681351 -10.116663 15.03414  
## Jul 2021 2.458744 -5.7638687 10.681357 -10.116657 15.03415  
## Aug 2021 2.458745 -5.7638678 10.681358 -10.116656 15.03415  
## Sep 2021 2.458745 -5.7638677 10.681358 -10.116656 15.03415  
## Oct 2021 2.458745 -5.7638677 10.681358 -10.116656 15.03415  
## Nov 2021 6.607394 -1.6152189 14.830007 -5.968007 19.18279  
## Dec 2021 4.651166 -3.5714470 12.873779 -7.924235 17.22657  
## Jan 2022 5.417891 -3.3662253 14.202007 -8.016255 18.85204  
## Feb 2022 7.637113 -1.1563772 16.430603 -5.811370 21.08560  
## Mar 2022 6.578925 -2.2147270 15.372577 -6.869805 20.02766  
## Apr 2022 3.433864 -5.3597911 12.227518 -10.014871 16.88260  
## May 2022 3.219940 -5.5737151 12.013595 -10.228795 16.66867  
## Jun 2022 3.220010 -5.5736452 12.013664 -10.228725 16.66874  
## Jul 2022 3.220019 -5.5736360 12.013674 -10.228716 16.66875  
## Aug 2022 3.220020 -5.5736348 12.013675 -10.228715 16.66875  
## Sep 2022 3.220020 -5.5736347 12.013675 -10.228714 16.66875  
## Oct 2022 3.220020 -5.5736346 12.013675 -10.228714 16.66875  
## Nov 2022 5.380024 -3.4136306 14.173679 -8.068710 18.82876  
## Dec 2022 5.397379 -3.3962756 14.191034 -8.051355 18.84611  
## Jan 2023 5.214360 -3.7066959 14.135417 -8.429218 18.85794  
## Feb 2023 6.907933 -2.0153054 15.831172 -6.738983 20.55485  
## Mar 2023 6.124039 -2.7992376 15.047315 -7.522935 19.77101  
## Apr 2023 3.710913 -5.2123645 12.634190 -9.936062 17.35789  
## May 2023 3.590073 -5.3332042 12.513350 -10.056902 17.23705  
## Jun 2023 3.590107 -5.3331702 12.513384 -10.056868 17.23708  
## Jul 2023 3.590111 -5.3331658 12.513388 -10.056863 17.23709  
## Aug 2023 3.590112 -5.3331652 12.513389 -10.056863 17.23709  
## Sep 2023 3.590112 -5.3331651 12.513389 -10.056863 17.23709  
## Oct 2023 3.590112 -5.3331651 12.513389 -10.056863 17.23709  
## Nov 2023 5.499094 -3.4241835 14.422371 -8.147881 19.14607  
## Dec 2023 4.875985 -4.0472918 13.799262 -8.770989 18.52296  
## Jan 2024 5.073078 -3.9583397 14.104495 -8.739283 18.88544  
## Feb 2024 6.238164 -2.7951080 15.271436 -7.577033 20.05336  
## Mar 2024 5.688943 -3.3443613 14.722247 -8.126304 19.50419  
## Apr 2024 4.034314 -4.9989911 13.067618 -9.780934 17.84956  
## May 2024 3.933348 -5.0999571 12.966652 -9.881900 17.74859  
## Jun 2024 3.933379 -5.0999256 12.966684 -9.881868 17.74863  
## Jul 2024 3.933383 -5.0999215 12.966688 -9.881864 17.74863  
## Aug 2024 3.933384 -5.0999210 12.966688 -9.881864 17.74863  
## Sep 2024 3.933384 -5.0999209 12.966689 -9.881864 17.74863  
## Oct 2024 3.933384 -5.0999209 12.966689 -9.881864 17.74863  
## Nov 2024 5.137078 -3.8962270 14.170382 -8.678170 18.95233  
## Dec 2024 4.975998 -4.0573066 14.009303 -8.839249 18.79125



### Conclusion