

Air Quality Analysis

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Instructions for running the code

How to run R-script on PC locally.

1. First, [install R](#).
2. Second, [install R-Studio](#).
3. Optionally in the future (do not do it now), [install RTools](#).
4. Open R-Studio and open the R-script.
5. Set working directory in menu Session/Set working directory/ To the source location (Optionally, this script does it itself).
6. This is an [R Markdown](#) Notebook. When you execute a code within the notebook, the results appear beneath the code.
7. Run the calculations by clicking the button Knit and select 'to HTML or Word'.
8. In the resulting window click 'Open in browser' and print it into PDF file or open for editing in MS Word or any other editor.

Setup

Set working directory

First, we should set some options and the current file location as the default working directory. All supporting files applied to the code should also be copied to this directory.

Installing packages and attaching libraries

Several common packages used below must be installed (if needed) and the libraries attached.

Air quality data load

Data structure

Here is the data structure.

```
## 'data.frame': 10075 obs. of 13 variables:
## $ Date : chr "01/02/2018" "01/08/2018" "01/14/2018" "01/20/2018" .
..
## $ Site_ID : int 170310001 170310001 170310001 170310001 170310001 170
310001 170310001 170310001 170310001 170310001 ...
## $ Daily_PM25 : num 12.9 14.7 8.9 11.7 6 5.2 17.8 21.9 6.2 8.5 ...
## $ Units : chr "ug/m3 LC" "ug/m3 LC" "ug/m3 LC" "ug/m3 LC" ...
## $ AQI : int 53 56 37 49 25 22 63 72 26 35 ...
## $ Site_Name : chr "VILLAGE GARAGE" "VILLAGE GARAGE" "VILLAGE GARAGE" "V
ILLAGE GARAGE" ...
## $ State_Code : int 17 17 17 17 17 17 17 17 17 17 ...
## $ State : chr "Illinois" "Illinois" "Illinois" "Illinois" ...
## $ County_Code: int 31 31 31 31 31 31 31 31 31 31 ...
## $ County : chr "Cook" "Cook" "Cook" "Cook" ...
## $ Site_Lat : num 41.7 41.7 41.7 41.7 41.7 ...
## $ Site_Long : num -87.7 -87.7 -87.7 -87.7 -87.7 ...
## $ POC : int 2 2 1 1 1 1 2 2 1 1 ...
```

Variable dictionary

All information about the data set attributes may be found in [Air Data: Air Quality Data Collected at Outdoor Monitors Across the city of Chicago](#)

Select, transform, and add variables

```
# head(df, 10)
# convert to date
df$Date <- as.Date(strptime(df$Date, format = "%m/%d/%Y", tz = "")) # as.Date
# remove insignificant columns
df <- df[, c(1, 3, 5, 6, 11:13)]
# add the weekend checking
df$Is_Weekend <- weekdays(df$Date) %in% c('Sunday', 'Saturday')
df$Site_Name <- as.factor(df$Site_Name)
#
sites <- levels(df$Site_Name)
# get
summary(df)
```

```
##           Date           Daily_PM25           AQI
## Min.      :2018-01-01   Min.      :-1.300   Min.      : 0.00
## 1st Qu.:2018-11-04   1st Qu.: 6.000   1st Qu.: 25.00
## Median :2019-08-21   Median : 8.800   Median : 37.00
## Mean     :2019-08-19   Mean     : 9.471   Mean     : 37.67
## 3rd Qu.:2020-06-05   3rd Qu.:12.000   3rd Qu.: 50.00
## Max.     :2021-04-25   Max.     :40.300   Max.     :113.00
##
##           Site_Name           Site_Lat           Site_Long
## NORTHBROOK WATER PLANT :1313   Min.      :41.58   Min.      :-87.88
## COM ED MAINTENANCE BLDG :1305   1st Qu.:41.75   1st Qu.: -87.80
## SPRINGFIELD PUMP STATION:1283   Median :41.86   Median : -87.75
## LIBERTY SCHOOL          :1251   Mean     :41.86   Mean     : -87.74
## VILLAGE GARAGE          :1189   3rd Qu.:41.97   3rd Qu.: -87.72
## REGIONAL OFFICE BUILDING: 894   Max.     :42.14   Max.     : -87.54
## (Other)                  :2840
##           POC           Is_Weekend
## Min.      :1.000   Mode :logical
## 1st Qu.:1.000   FALSE:7183
## Median :1.000   TRUE :2892
## Mean     :1.248
## 3rd Qu.:1.000
## Max.     :3.000
##
```

Descriptive statistics

Let us take a look at the common summary of the data set.

```
summary(df)

##           Date           Daily_PM25           AQI
## Min.      :2018-01-01   Min.      :-1.300   Min.      : 0.00
## 1st Qu.:2018-11-04   1st Qu.: 6.000   1st Qu.: 25.00
## Median :2019-08-21   Median : 8.800   Median : 37.00
## Mean     :2019-08-19   Mean     : 9.471   Mean     : 37.67
## 3rd Qu.:2020-06-05   3rd Qu.:12.000   3rd Qu.: 50.00
## Max.     :2021-04-25   Max.     :40.300   Max.     :113.00
##
##           Site_Name           Site_Lat           Site_Long
## NORTHBROOK WATER PLANT :1313   Min.      :41.58   Min.      :-87.88
## COM ED MAINTENANCE BLDG :1305   1st Qu.:41.75   1st Qu.: -87.80
```

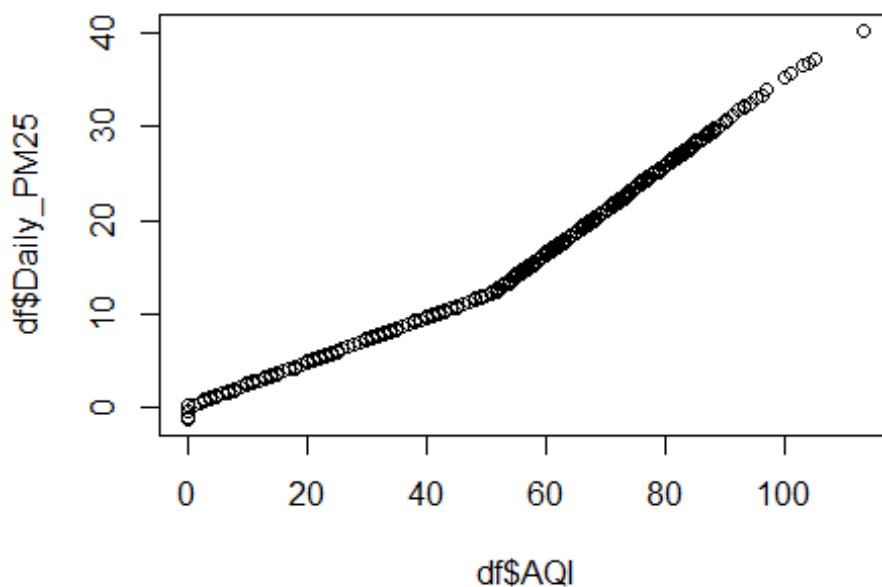
```
## SPRINGFIELD PUMP STATION:1283 Median :41.86 Median :-87.75
## LIBERTY SCHOOL :1251 Mean :41.86 Mean :-87.74
## VILLAGE GARAGE :1189 3rd Qu.:41.97 3rd Qu.: -87.72
## REGIONAL OFFICE BUILDING: 894 Max. :42.14 Max. : -87.54
## (Other) :2840
## POC Is_Weekend
## Min. :1.000 Mode :logical
## 1st Qu.:1.000 FALSE:7183
## Median :1.000 TRUE :2892
## Mean :1.248
## 3rd Qu.:1.000
## Max. :3.000
##
```

There are no missing, nor mistakable values.

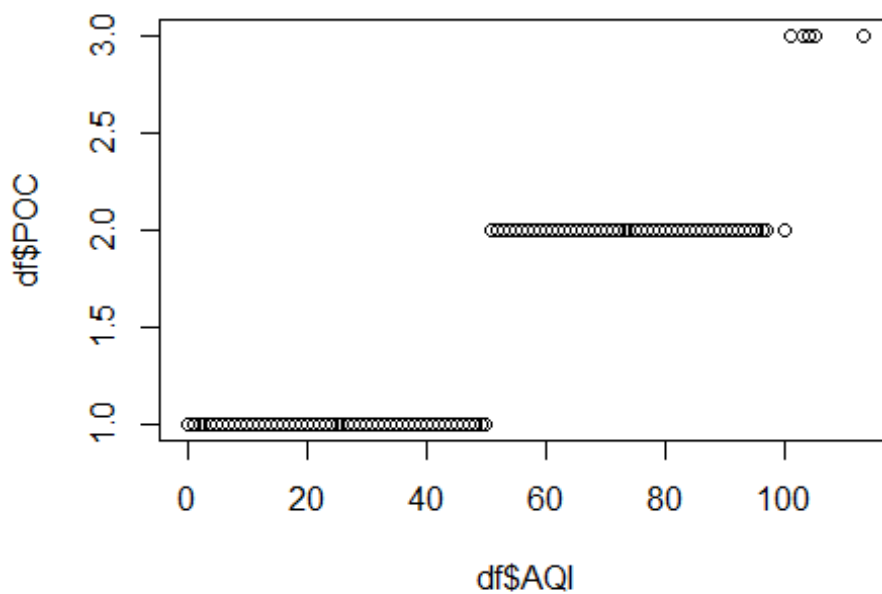
Correlation between the variables

Which variables are independent?

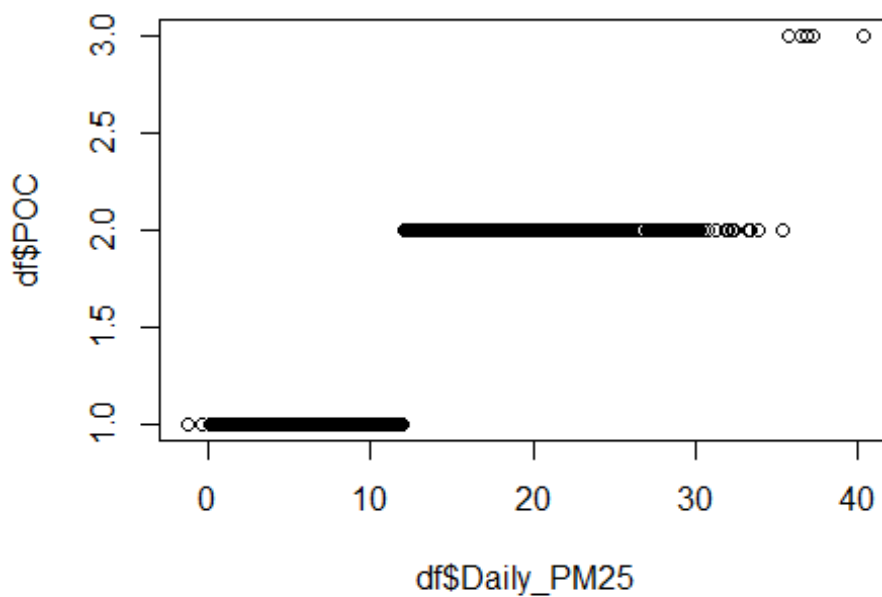
```
plot(df$AQI, df$Daily_PM25)
```



```
plot(df$AQI, df$POC)
```



```
plot( df$Daily_PM25, df$POC)
```



Chicago Air Quality monitoring site

```
img.file <- "chicago.png"
```

```
# read a sample file (R Logo)
```

```
img <- readPNG(img.file)
```

```
# get summary
```

```
site_obs <- df[which(year(df$Date) == 2018), c(1, 2, 4:6)] %>% # pivot_longer
```

```
(-Date) %>%
```

```
group_by(Site_Name) %>%
```

```

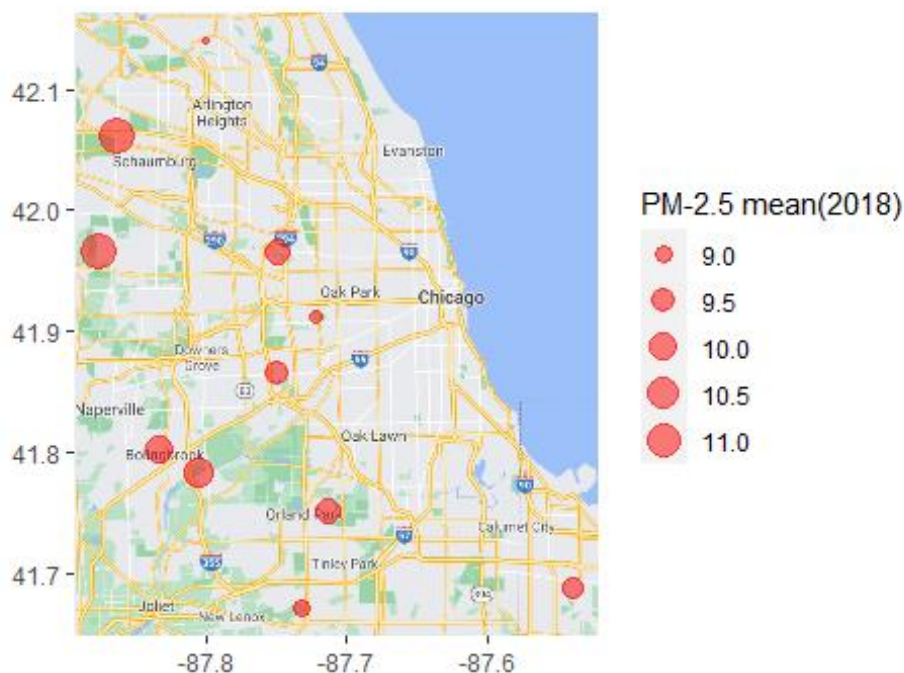
summarize(mean = mean(Daily_PM25), x = mean(Site_Long), y = mean(Site_Lat))
# %>% fashion()

## `summarise()` ungrouping output (override with `.groups` argument)

aspect.ratio = 754/631 # Height to Width ratio of pixel sizes

ggplot() +
  annotation_custom(rasterGrob(img, width = unit(1, "npc"), height = unit(1,
"npc")), -Inf, Inf, -Inf, Inf) +
  geom_point(
    aes(
      x = as.numeric(x),
      y = as.numeric(y),
      size = as.numeric(mean)
    ),
    data = site_obs,
    alpha = 0.5,
    col = "red"
  ) +
  labs(
    x = "",
    y = "",
    size = "PM-2.5 mean(2018)"
  ) + theme(aspect.ratio=aspect.ratio)

```



Box and whiskers plots

Boxplot compactly displays the distribution of a continuous variable. It visualizes five summary statistics (the median, two hinges and two whiskers), and all “outlying” points individually.

```

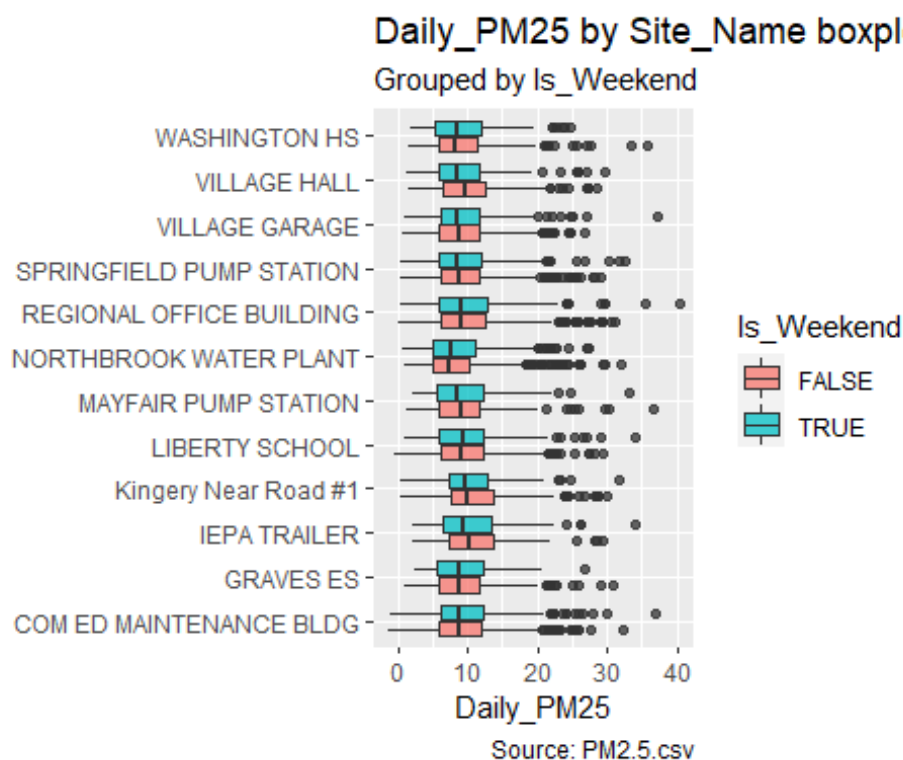
# get the boxplot
ggplot() + geom_boxplot(data = df,
  aes(

```

```

    x = Site_Name,
    y = Daily_PM25,
    fill = factor(Is_Weekend)
  ),
  alpha = 0.75) + labs(
    title = paste(names(df)[2], "by", names(df)[4], "boxplot"),
    subtitle = paste("Grouped by", names(df)[8]),
    caption = paste("Source:", fileName),
    x = "",
    fill = names(df)[8]
  ) +
  coord_flip()

```



Comparing the different boxplots above...

Smoothed density estimates

In this section we computed and drawn for every continuous variable its kernel density estimate, which is a smoothed version of the histogram. This is an alternative to the histogram for continuous data that comes from an underlying smooth distribution.

```

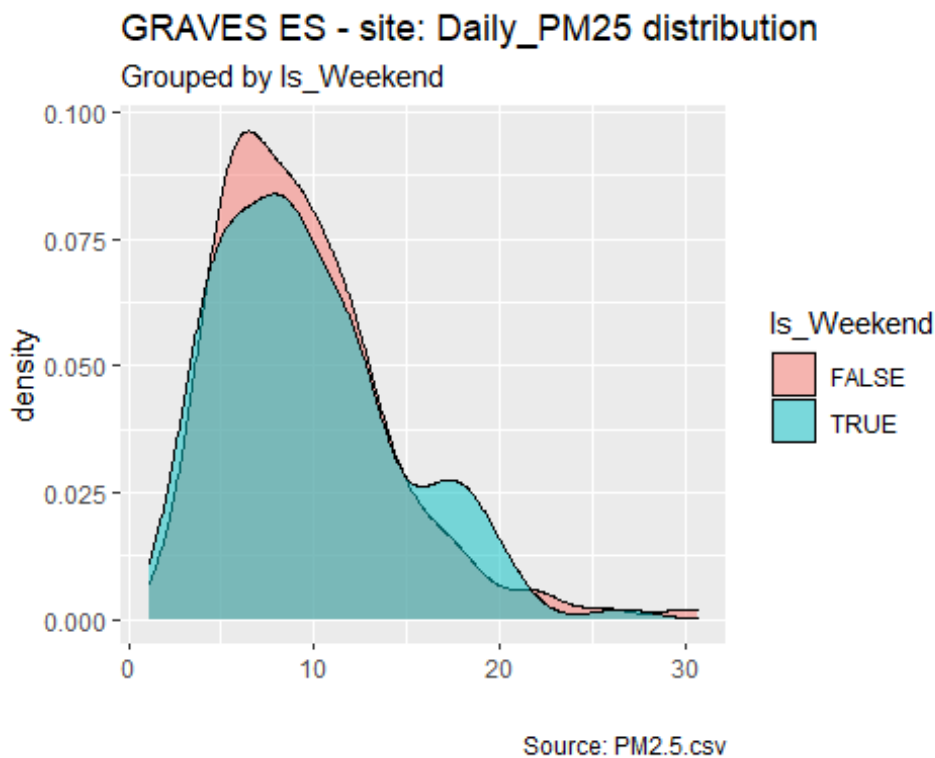
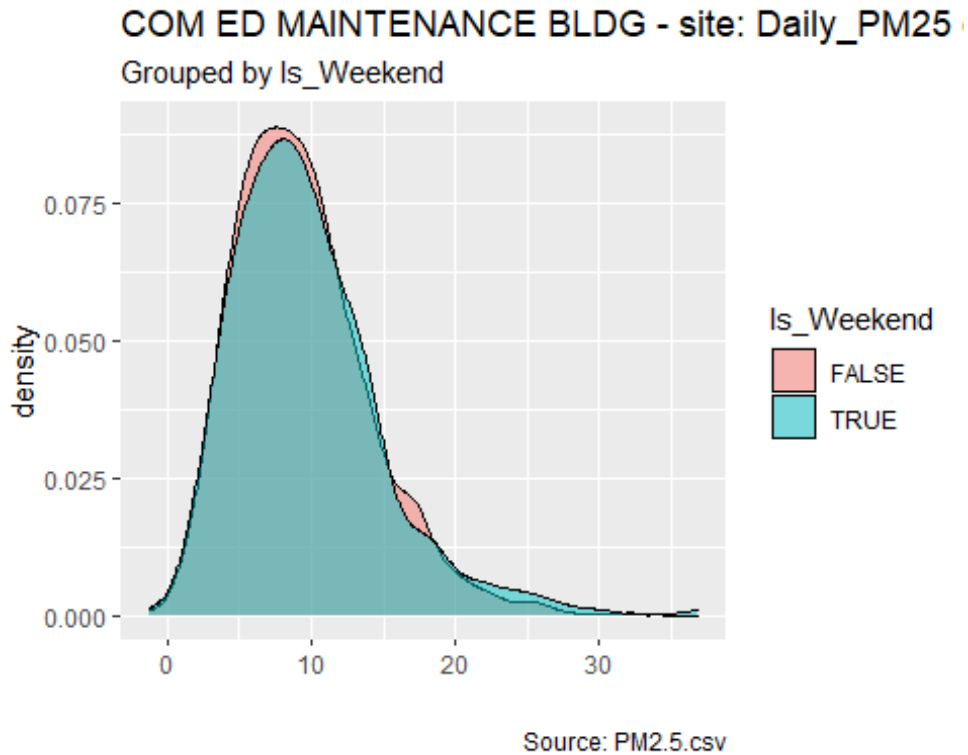
# Loop over groups and numeric variables
for (site in sites)
  print(
    ggplot() + geom_density(
      data = df[df$Site_Name == site, ],
      aes(
        x = Daily_PM25,
        fill = factor(Is_Weekend)
      ),
      alpha = 0.5
    ) +
    labs(

```

```

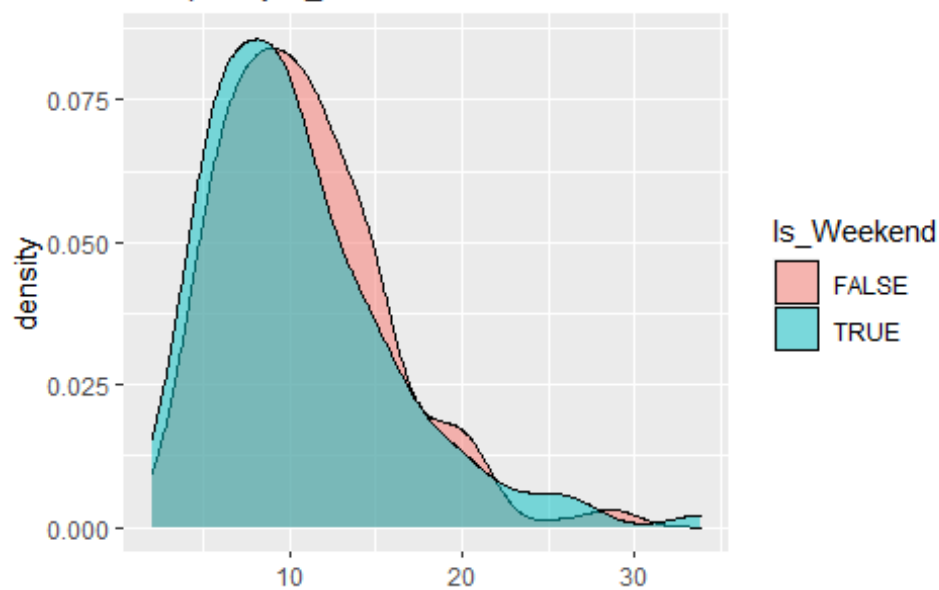
title = paste(site, "- site:", names(df)[2], "distribution"),
subtitle = paste("Grouped by", names(df)[8]),
caption = paste("Source:", fileName),
x = "",
fill = names(df)[8]
)
)

```



IEPA TRAILER - site: Daily_PM25 distribution

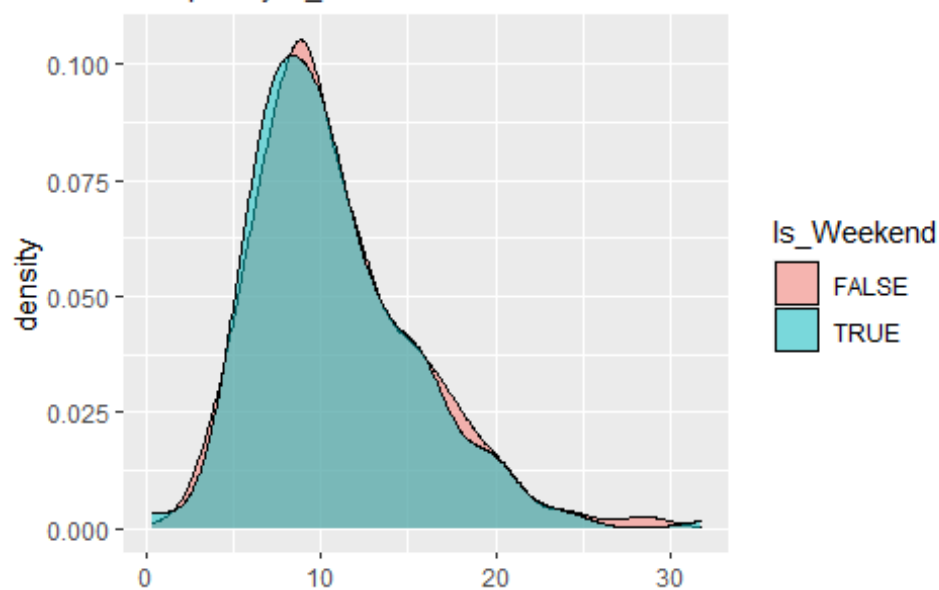
Grouped by Is_Weekend



Source: PM2.5.csv

Kingery Near Road #1 - site: Daily_PM25 distribution

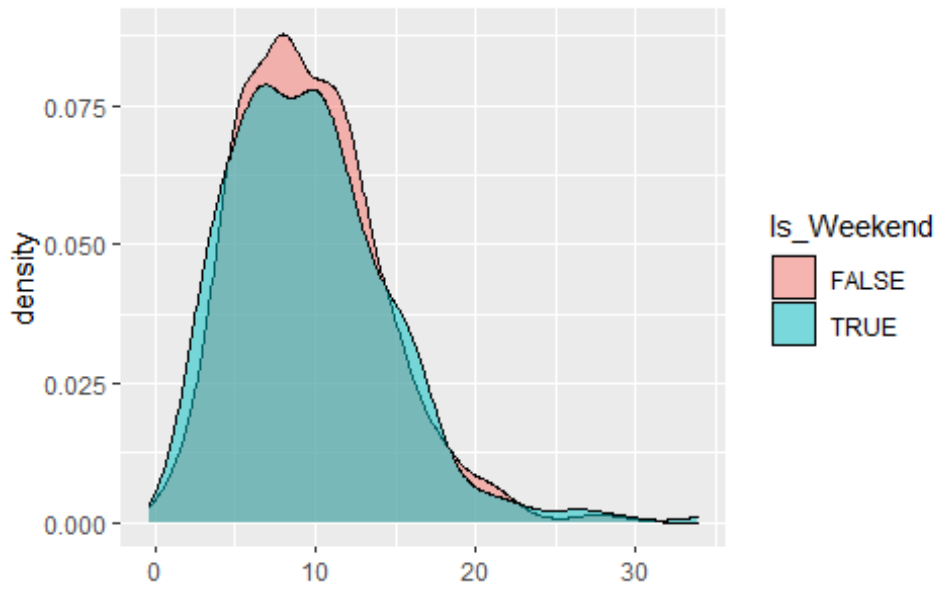
Grouped by Is_Weekend



Source: PM2.5.csv

LIBERTY SCHOOL - site: Daily_PM25 distribution

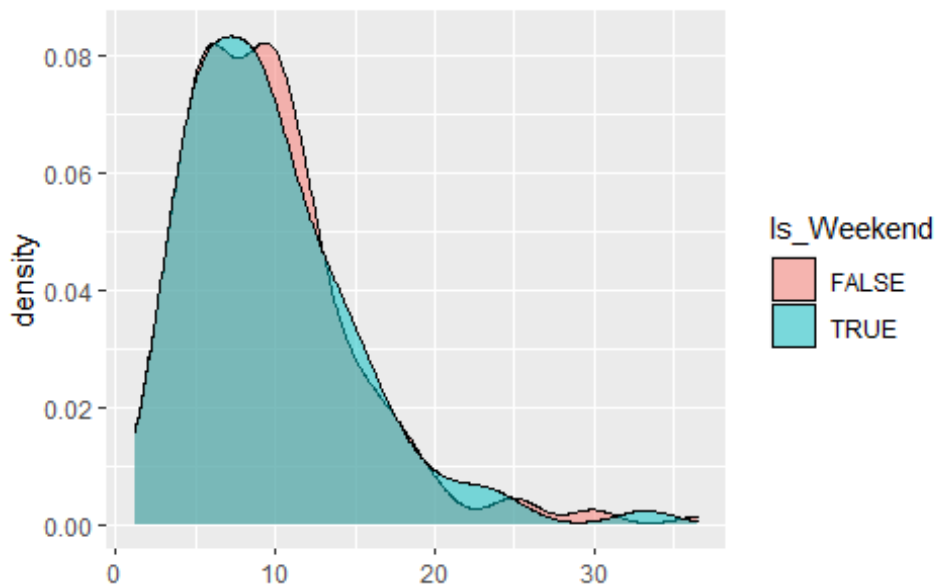
Grouped by Is_Weekend



Source: PM2.5.csv

MAYFAIR PUMP STATION - site: Daily_PM25 distribution

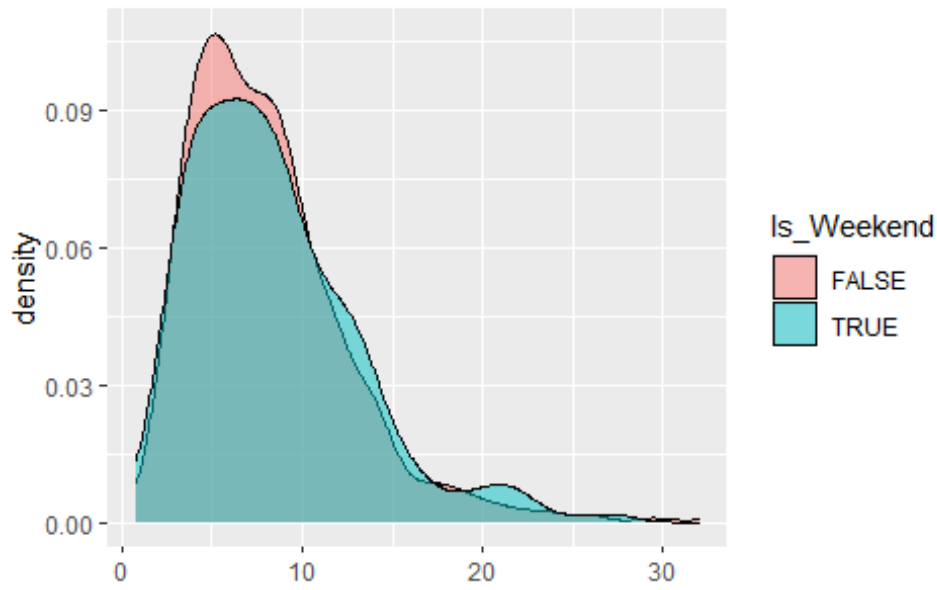
Grouped by Is_Weekend



Source: PM2.5.csv

NORTHBROOK WATER PLANT - site: Daily_PM25 c

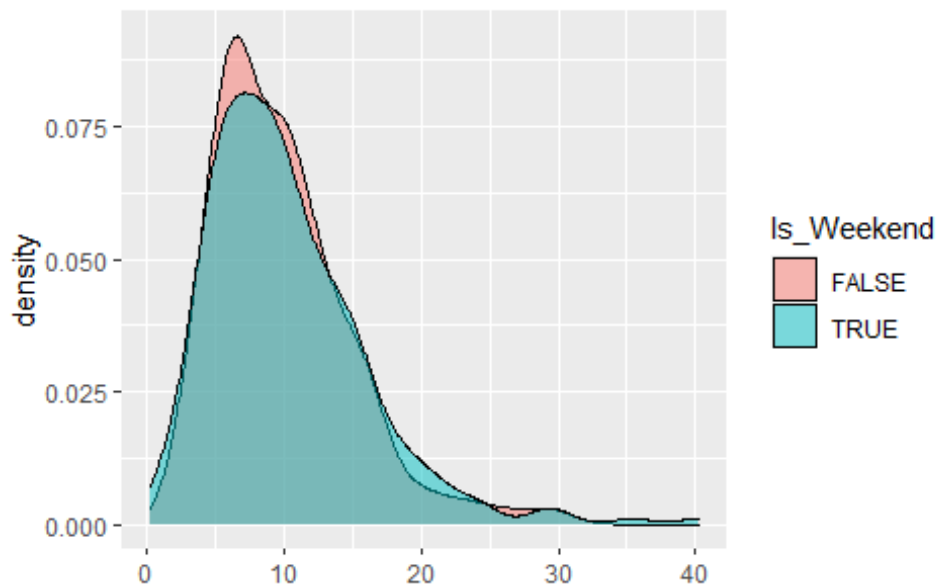
Grouped by Is_Weekend



Source: PM2.5.csv

REGIONAL OFFICE BUILDING - site: Daily_PM25 di

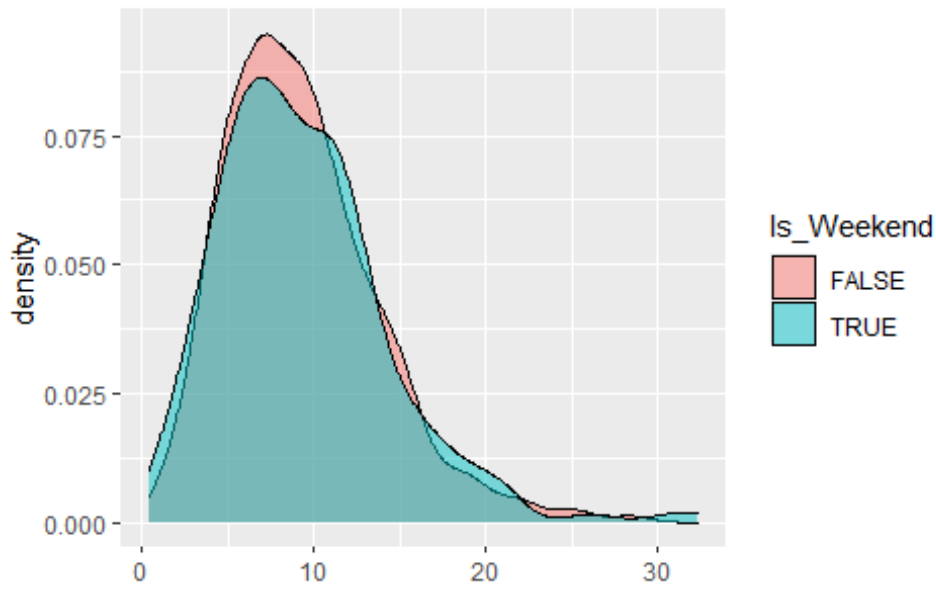
Grouped by Is_Weekend



Source: PM2.5.csv

SPRINGFIELD PUMP STATION - site: Daily_PM25 (

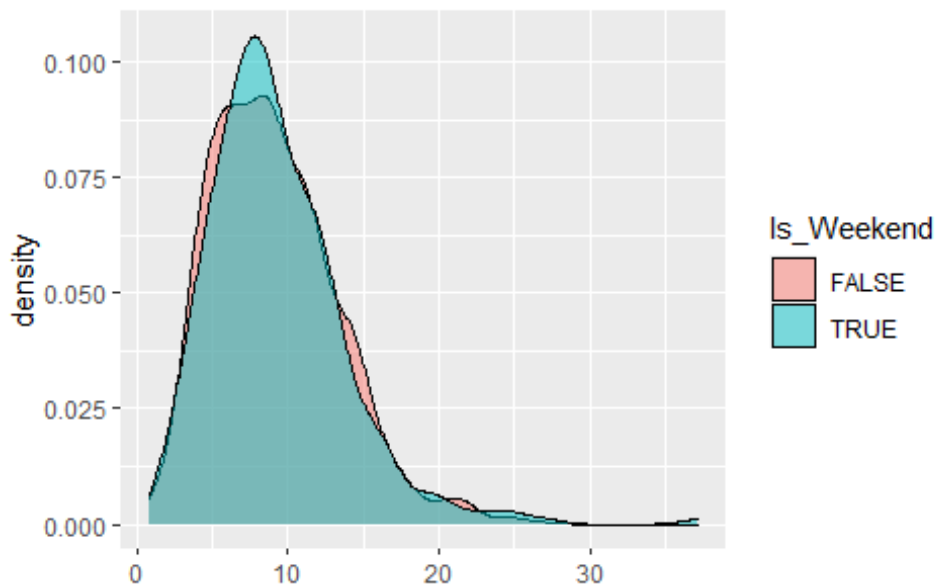
Grouped by Is_Weekend



Source: PM2.5.csv

VILLAGE GARAGE - site: Daily_PM25 distribution

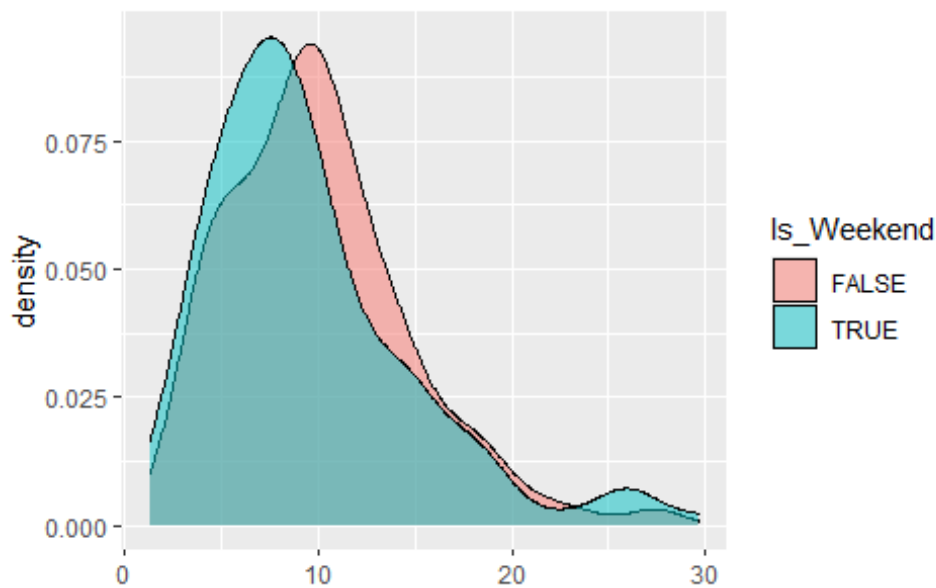
Grouped by Is_Weekend



Source: PM2.5.csv

VILLAGE HALL - site: Daily_PM25 distribution

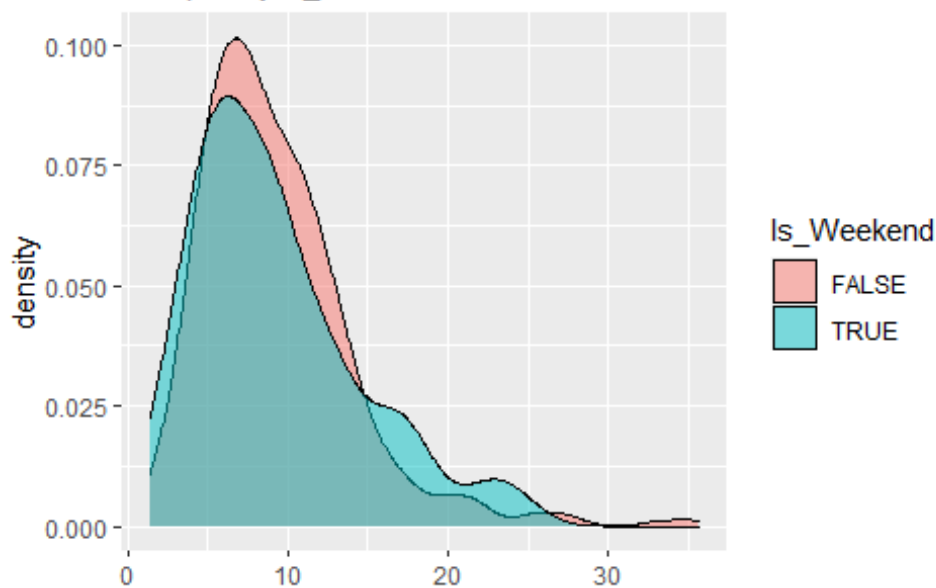
Grouped by Is_Weekend



Source: PM2.5.csv

WASHINGTON HS - site: Daily_PM25 distribution

Grouped by Is_Weekend



Source: PM2.5.csv

Analyzing the above distributions...

Sites time series

Air Quality Index trends

We used Machine Learning prediction model of the Prophet package to investigate the many years trends with different periodicity: weekly, monthly, yearly, and the total history trend. The closest future forecasts were also done formally. However, these predictions have low sense because of drastically influence of daily oscillations of the wind, humidity, precipitation, and so on. All these factors produce the relatively wide confidence range as may be seen below.

Machine Learning model

'Prophet' package was used for making 30 days forecast.

Results of the calculations are presented visually as the set of charts below. For every of the sites which detect pollutions we got two plots. The first shows the observed level of pollution (PM 2.5) as black dots, the forward and backward prediction curve (blue line), and the 95% confidence interval as the blue band along conveyed the predictions.

It is interesting that total history trends may differ for different sites, also may differ weekly trends. However yearly trends look very similar, and almost all of them are maximized in January.

Maybe, local factors should be used to investigate these pictures deeper.

```
# the warning and error information
logWarning <-
  function(w) {
    print(paste(site, "prophet warning", w))
  }
logError <- function(e) {
  print(paste(site, "prophet error", e))
}
#
# Loop over groups and numeric variables
for (site in sites) {
  #
  # create a data frame for further treatment
  df.site <-
    data.frame(
      ds = df$Date[df$Site_Name == site],
      y = df$Daily_PM25[df$Site_Name == site],
      row.names = NULL,
      stringsAsFactors = FALSE
    )
  #
  # optimize the model
  model <- tryCatch(
    withCallingHandlers(
      prophet(
        df = df.site,
        yearly.seasonality = TRUE,
        weekly.seasonality = TRUE,
        daily.seasonality = FALSE
      ),
      warning = function(w)
        logWarning(w)
    ),
    error = function(e)
      logError(e)
  )
  # prepare the template for the future predictions
  future <-
    make_future_dataframe(
      model,
      periods = nfor,
      freq = "day",

```

```

    include_history = TRUE
  )
  # forecast for 'nfor' days ahead (it also includes non trading days)
  fcast <- predict(model, future)
  print(paste("Forecast for the Site:", site))
  print(head(fcast))
  print(tail(fcast))
  # plot the forecast with confidence intervals
  print(plot(
    model,
    fcast,
    xlabel = paste("Site:", site),
    ylabel = "Daily PM 2.5"
  ))

  # plot of the trend components of the forecast
  prophet_plot_components(model, fcast)
}

## [1] "Forecast for the Site: COM ED MAINTENANCE BLDG"
##           ds      trend additive_terms additive_terms_lower additive_terms_upper
## 1 2018-01-01 8.329630   -0.09100001      -0.09100001      -0.09100001
## 2 2018-01-02 8.336514   -0.55601791     -0.55601791     -0.55601791
## 3 2018-01-02 8.336514   -0.55601791     -0.55601791     -0.55601791
## 4 2018-01-03 8.343398   -0.39249604     -0.39249604     -0.39249604
## 5 2018-01-04 8.350282   -0.33964498     -0.33964498     -0.33964498
## 6 2018-01-05 8.357166   -0.13879232     -0.13879232     -0.13879232
##           weekly weekly_lower weekly_upper      yearly yearly_lower yearly_upper
## 1 0.10414021 0.10414021 0.10414021 -0.1951402 -0.1951402 -0.1951402
## 2 -0.34590261 -0.34590261 -0.34590261 -0.2101153 -0.2101153 -0.2101153
## 3 -0.34590261 -0.34590261 -0.34590261 -0.2101153 -0.2101153 -0.2101153
## 4 -0.17301338 -0.17301338 -0.17301338 -0.2194827 -0.2194827 -0.2194827
## 5 -0.11503008 -0.11503008 -0.11503008 -0.2246149 -0.2246149 -0.2246149
## 6 0.08812316 0.08812316 0.08812316 -0.2269155 -0.2269155 -0.2269155
## multiplicative_terms multiplicative_terms_lower multiplicative_terms_upper
## 1 0 0
## 2 0 0
## 3 0 0

```

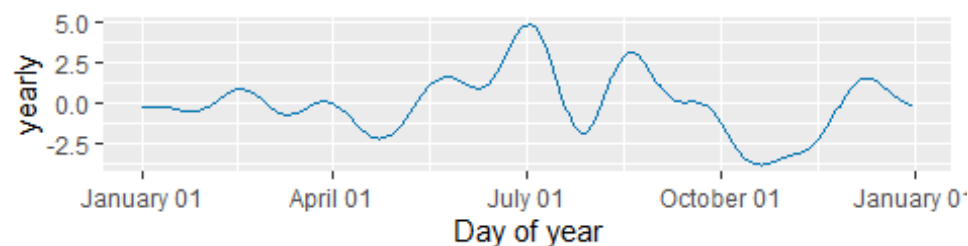
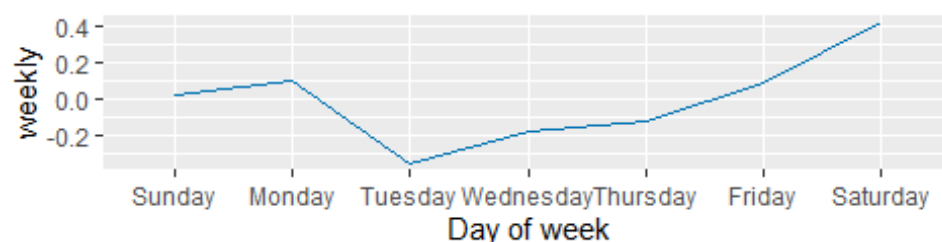
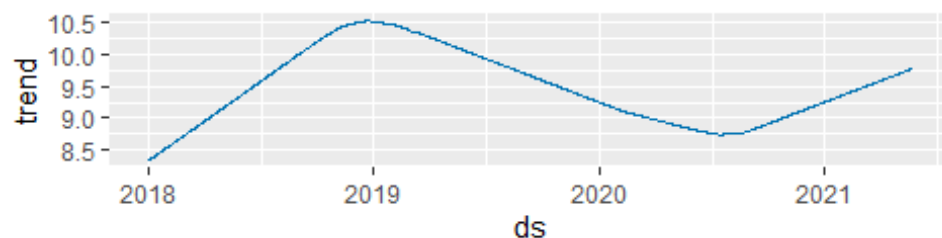
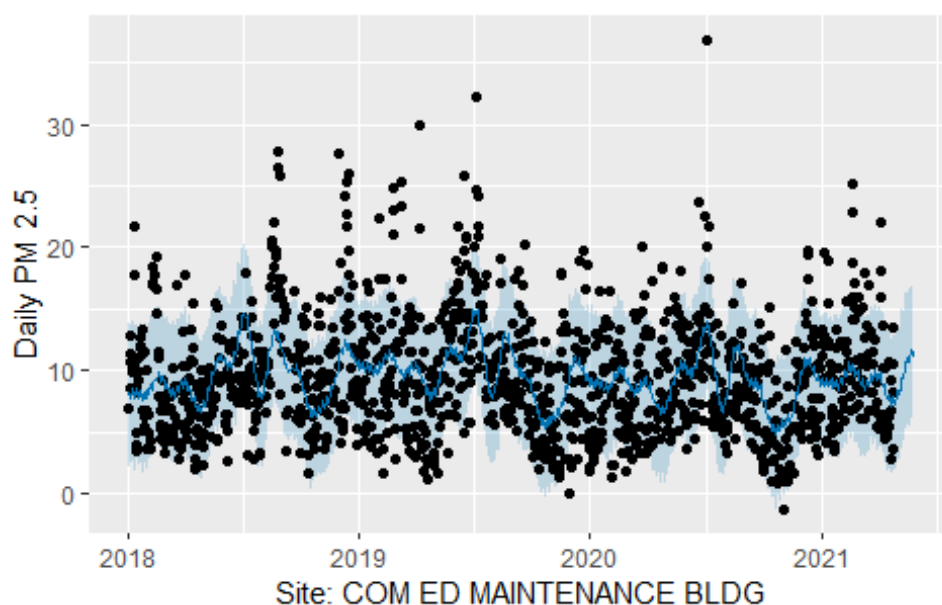
```

0
## 4          0          0
0
## 5          0          0
0
## 6          0          0
0
##   yhat_lower yhat_upper trend_lower trend_upper   yhat
## 1   2.385418   13.92328    8.329630    8.329630  8.238630
## 2   1.720328   13.58191    8.336514    8.336514  7.780496
## 3   1.931210   13.30879    8.336514    8.336514  7.780496
## 4   2.260119   13.51676    8.343398    8.343398  7.950902
## 5   2.578317   13.82250    8.350282    8.350282  8.010637
## 6   2.894841   13.49446    8.357166    8.357166  8.218373
##           ds      trend additive_terms additive_terms_lower
## 1330 2021-05-20 9.773255      1.323878      1.323878
## 1331 2021-05-21 9.776971      1.602526      1.602526
## 1332 2021-05-22 9.780686      1.993343      1.993343
## 1333 2021-05-23 9.784402      1.631559      1.631559
## 1334 2021-05-24 9.788118      1.736948      1.736948
## 1335 2021-05-25 9.791833      1.291070      1.291070
##           additive_terms_upper      weekly weekly_lower weekly_upper   yearly
## 1330      1.323878 -0.11503008 -0.11503008 -0.11503008 1.438908
## 1331      1.602526  0.08812316  0.08812316  0.08812316 1.514403
## 1332      1.993343  0.42143216  0.42143216  0.42143216 1.571911
## 1333      1.631559  0.02025054  0.02025054  0.02025054 1.611308
## 1334      1.736948  0.10414021  0.10414021  0.10414021 1.632807
## 1335      1.291070 -0.34590261 -0.34590261 -0.34590261 1.636973
##           yearly_lower yearly_upper multiplicative_terms multiplicative_terms_l
ower
## 1330      1.438908      1.438908          0
0
## 1331      1.514403      1.514403          0
0
## 1332      1.571911      1.571911          0
0
## 1333      1.611308      1.611308          0
0
## 1334      1.632807      1.632807          0
0
## 1335      1.636973      1.636973          0
0
##           multiplicative_terms_upper yhat_lower yhat_upper trend_lower trend_up
per
## 1330          0  5.505726  16.81108    9.766582    9.777
591
## 1331          0  5.451550  16.63148    9.769883    9.781
891
## 1332          0  5.990348  17.56768    9.773007    9.786
101
## 1333          0  6.115011  16.83029    9.776375    9.790
284
## 1334          0  6.145271  16.90191    9.779640    9.794
535

```



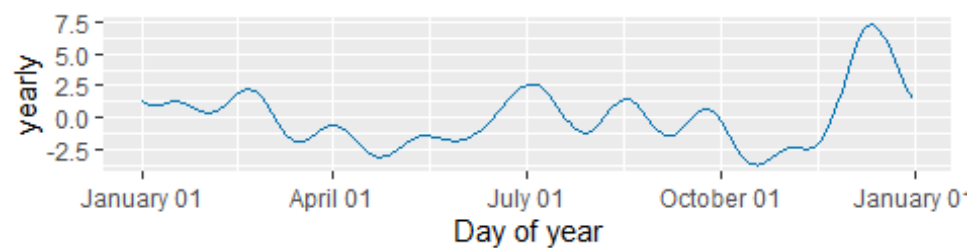
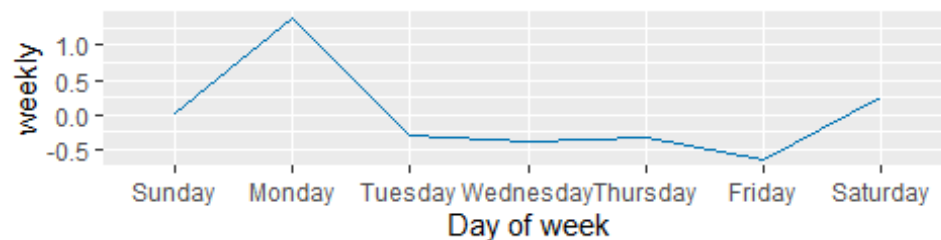
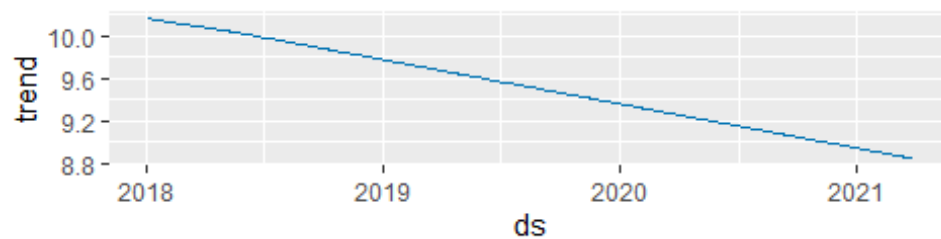
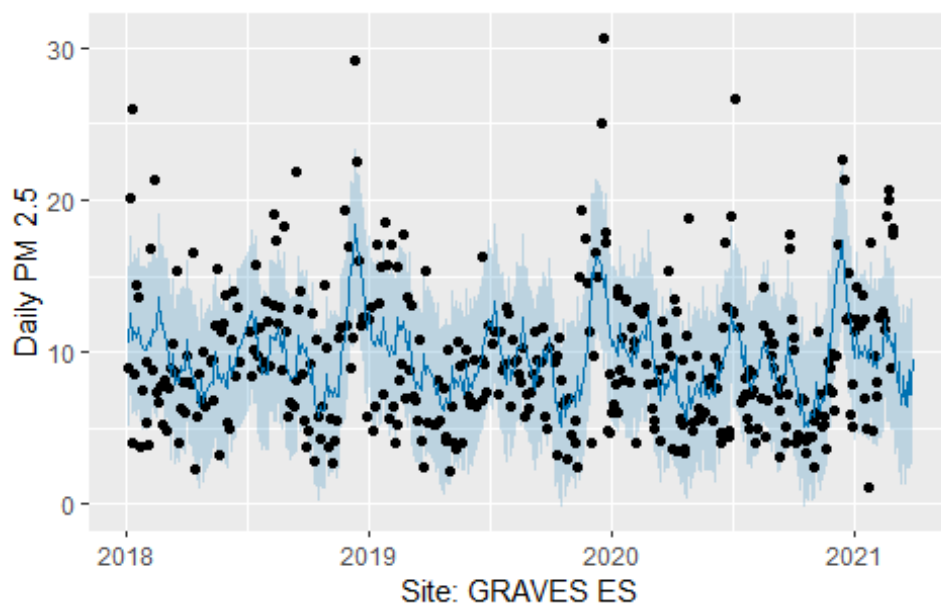
```
## 1335          0    6.074235    16.57512    9.782404    9.799
022
##          yhat
## 1330 11.09713
## 1331 11.37950
## 1332 11.77403
## 1333 11.41596
## 1334 11.52507
## 1335 11.08290
```



```
## [1] "Forecast for the Site: GRAVES ES"
##          ds    trend additive_terms additive_terms_lower additive_terms_u
pper
```

## 1	2018-01-05	10.15729	0.3419697	0.3419697	0.341	
9697						
## 2	2018-01-08	10.15445	2.3489673	2.3489673	2.348	
9673						
## 3	2018-01-09	10.15351	0.6950721	0.6950721	0.695	
0721						
## 4	2018-01-11	10.15162	0.7745979	0.7745979	0.774	
5979						
## 5	2018-01-14	10.14879	1.2514906	1.2514906	1.251	
4906						
## 6	2018-01-17	10.14595	0.8765706	0.8765706	0.876	
5706						
##	weekly	weekly_lower	weekly_upper	yearly	yearly_lower	yearly_upper
## 1	-0.62970351	-0.62970351	-0.62970351	0.9716733	0.9716733	0.9716733
3						
## 2	1.37739903	1.37739903	1.37739903	0.9715683	0.9715683	0.9715683
3						
## 3	-0.30980206	-0.30980206	-0.30980206	1.0048741	1.0048741	1.0048741
1						
## 4	-0.32002209	-0.32002209	-0.32002209	1.0946200	1.0946200	1.0946200
0						
## 5	0.02749653	0.02749653	0.02749653	1.2239941	1.2239941	1.2239941
1						
## 6	-0.39183038	-0.39183038	-0.39183038	1.2684009	1.2684009	1.2684009
9						
##	multiplicative_terms	multiplicative_terms_lower	multiplicative_terms_upper			
## 1		0		0		
0						
## 2		0		0		
0						
## 3		0		0		
0						
## 4		0		0		
0						
## 5		0		0		
0						
## 6		0		0		
0						
##	yhat_lower	yhat_upper	trend_lower	trend_upper	yhat	
## 1	5.139956	15.57060	10.15729	10.15729	10.49926	
## 2	7.252156	17.68401	10.15445	10.15445	12.50342	
## 3	5.576058	16.11327	10.15351	10.15351	10.84858	
## 4	5.852721	15.86588	10.15162	10.15162	10.92622	
## 5	6.136674	16.55470	10.14879	10.14879	11.40028	
## 6	5.788781	16.20735	10.14595	10.14595	11.02252	
##	ds	trend	additive_terms	additive_terms_lower		
## 434	2021-03-24	8.852775	-1.6131484	-1.6131484		
## 435	2021-03-25	8.851641	-1.4183122	-1.4183122		
## 436	2021-03-26	8.850508	-1.6103678	-1.6103678		
## 437	2021-03-27	8.849375	-0.6261643	-0.6261643		
## 438	2021-03-28	8.848242	-0.7505285	-0.7505285		
## 439	2021-03-29	8.847109	0.6771264	0.6771264		

##	additive_terms_upper	weekly	weekly_lower	weekly_upper	yearly
## 434	-1.6131484	-0.39183038	-0.39183038	-0.39183038	-1.2213181
## 435	-1.4183122	-0.32002209	-0.32002209	-0.32002209	-1.0982901
## 436	-1.6103678	-0.62970351	-0.62970351	-0.62970351	-0.9806643
## 437	-0.6261643	0.24646248	0.24646248	0.24646248	-0.8726267
## 438	-0.7505285	0.02749653	0.02749653	0.02749653	-0.7780250
## 439	0.6771264	1.37739903	1.37739903	1.37739903	-0.7002727
##	yearly_lower	yearly_upper	multiplicative_terms	multiplicative_terms_lo	wer
## 434	-1.2213181	-1.2213181		0	0
## 435	-1.0982901	-1.0982901		0	0
## 436	-0.9806643	-0.9806643		0	0
## 437	-0.8726267	-0.8726267		0	0
## 438	-0.7780250	-0.7780250		0	0
## 439	-0.7002727	-0.7002727		0	0
##	multiplicative_terms_upper	yhat_lower	yhat_upper	trend_lower	trend_upper
## 434		0	2.404983	12.77609	8.852721
55					8.8528
## 435		0	2.245404	12.81070	8.851582
28					8.8517
## 436		0	2.021368	12.60207	8.850442
02					8.8506
## 437		0	3.041026	13.60951	8.849306
80					8.8494
## 438		0	2.607231	13.50631	8.848165
55					8.8483
## 439		0	4.255519	14.74509	8.847025
26					8.8472
##	yhat				
## 434	7.239626				
## 435	7.433329				
## 436	7.240140				
## 437	8.223211				
## 438	8.097713				
## 439	9.524235				



[1] "Forecast for the Site: IEPA TRAILER"

##	ds	trend	additive_terms	additive_terms_lower	additive_terms_upper
## 1	2018-01-05	11.33179	1.0452315	1.0452315	1.0452315
## 2	2018-01-08	11.32879	0.6726085	0.6726085	0.6726085
## 3	2018-01-11	11.32580	-0.1616853	-0.1616853	-0.1616853
## 4	2018-01-14	11.32280	-0.4987341	-0.4987341	-0.4987341
## 5	2018-01-17	11.31980	1.0070045	1.0070045	1.0070045

0045

## 6	2018-01-20	11.31681	1.6630934	1.6630934	1.663
------	------------	----------	-----------	-----------	-------

0934

##	weekly	weekly_lower	weekly_upper	yearly	yearly_lower	yearly_upper
## 1	0.5791749	0.5791749	0.5791749	0.4660566	0.4660566	0.4660566
## 2	0.4584748	0.4584748	0.4584748	0.2141337	0.2141337	0.2141337
## 3	-0.3855759	-0.3855759	-0.3855759	0.2238906	0.2238906	0.2238906
## 4	-0.9300307	-0.9300307	-0.9300307	0.4312967	0.4312967	0.4312967
## 5	0.2531216	0.2531216	0.2531216	0.7538830	0.7538830	0.7538830
## 6	0.5535689	0.5535689	0.5535689	1.1095246	1.1095246	1.1095246

##	multiplicative_terms	multiplicative_terms_lower	multiplicative_terms_upper
## 1	0	0	0
## 2	0	0	0
## 3	0	0	0
## 4	0	0	0
## 5	0	0	0
## 6	0	0	0

##	yhat_lower	yhat_upper	trend_lower	trend_upper	yhat
## 1	6.533203	18.47558	11.33179	11.33179	12.37702
## 2	6.093959	17.50568	11.32879	11.32879	12.00140
## 3	4.915061	17.02552	11.32580	11.32580	11.16411
## 4	4.905455	16.80194	11.32280	11.32280	10.82407
## 5	5.814650	17.97432	11.31980	11.31980	12.32681
## 6	7.038889	18.73240	11.31681	11.31681	12.97990

##	ds	trend	additive_terms	additive_terms_lower
## 397	2021-03-24	10.15899	-0.550605080	-0.550605080
## 398	2021-03-25	10.15799	-1.071726281	-1.071726281
## 399	2021-03-26	10.15700	0.009046256	0.009046256
## 400	2021-03-27	10.15600	0.094929023	0.094929023
## 401	2021-03-28	10.15500	-1.284637214	-1.284637214
## 402	2021-03-29	10.15400	0.197640422	0.197640422

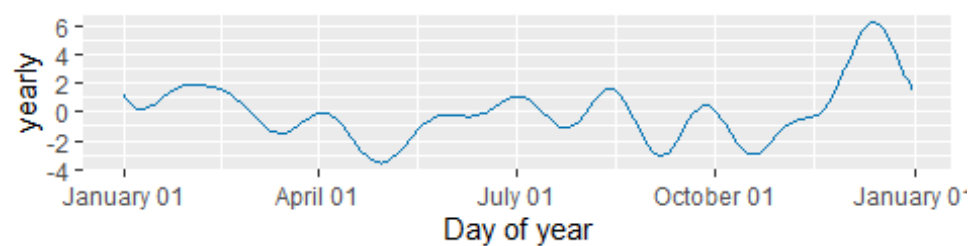
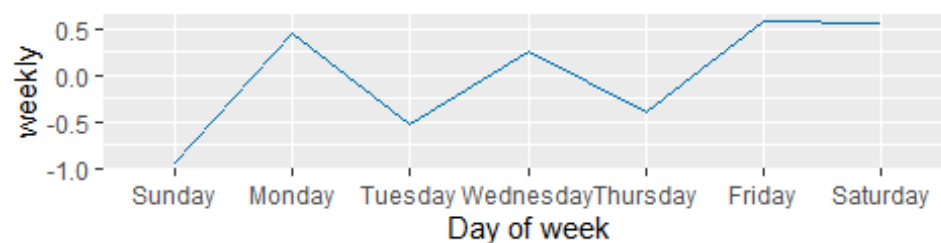
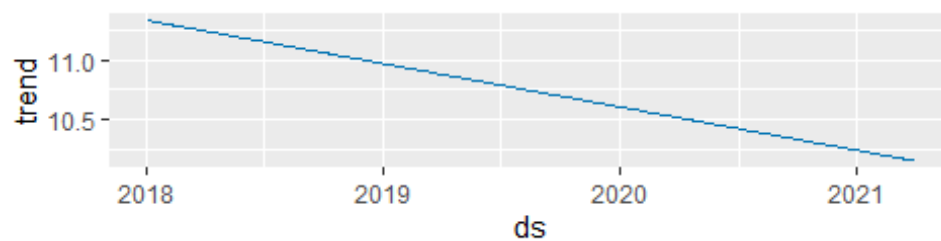
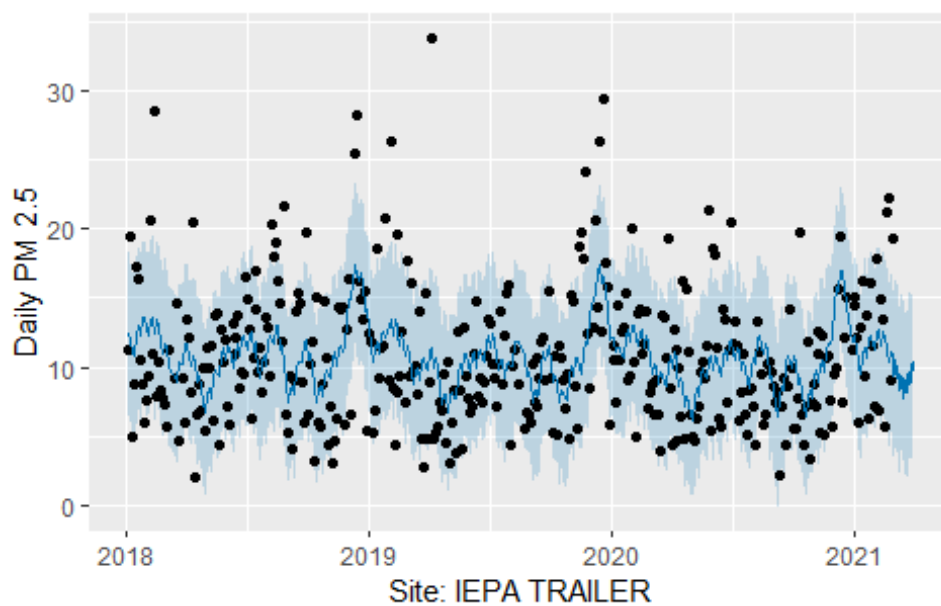
##	additive_terms_upper	weekly	weekly_lower	weekly_upper	yearly
## 397	-0.550605080	0.2531216	0.2531216	0.2531216	-0.8037266
## 398	-1.071726281	-0.3855759	-0.3855759	-0.3855759	-0.6861504
## 399	0.009046256	0.5791749	0.5791749	0.5791749	-0.5701286
## 400	0.094929023	0.5535689	0.5535689	0.5535689	-0.4586398
## 401	-1.284637214	-0.9300307	-0.9300307	-0.9300307	-0.3546065
## 402	0.197640422	0.4584748	0.4584748	0.4584748	-0.2608344

##	yearly_lower	yearly_upper	multiplicative_terms	multiplicative_terms_lower
## 397	-0.8037266	-0.8037266	0	0
## 398	-0.6861504	-0.6861504	0	0
## 399	-0.5701286	-0.5701286	0	0
## 400	-0.4586398	-0.4586398	0	0

```

0
## 401    -0.3546065    -0.3546065                0
0
## 402    -0.2608344    -0.2608344                0
0
##      multiplicative_terms_upper yhat_lower yhat_upper trend_lower trend_upper
er
## 397                0    3.489523    15.57161    10.15899    10.158
99
## 398                0    3.386440    15.07081    10.15799    10.158
00
## 399                0    4.265575    16.64487    10.15699    10.157
00
## 400                0    4.474404    16.05644    10.15600    10.156
00
## 401                0    3.266808    15.14861    10.15500    10.155
00
## 402                0    4.805091    16.33075    10.15400    10.154
00
##          yhat
## 397  9.608389
## 398  9.086269
## 399 10.166042
## 400 10.250925
## 401  8.870359
## 402 10.351637

```



```
## [1] "Forecast for the Site: Kingery Near Road #1"
##           ds      trend additive_terms additive_terms_lower additive_terms_u
pper
## 1 2019-03-01 10.61011      0.2676091      0.2676091      0.267
6091
## 2 2019-03-02 10.61065      0.2651178      0.2651178      0.265
1178
## 3 2019-03-03 10.61119     -0.6868764     -0.6868764     -0.686
8764
## 4 2019-03-04 10.61173     -0.1743685     -0.1743685     -0.174
3685
## 5 2019-03-05 10.61227      0.4959430      0.4959430      0.495
```

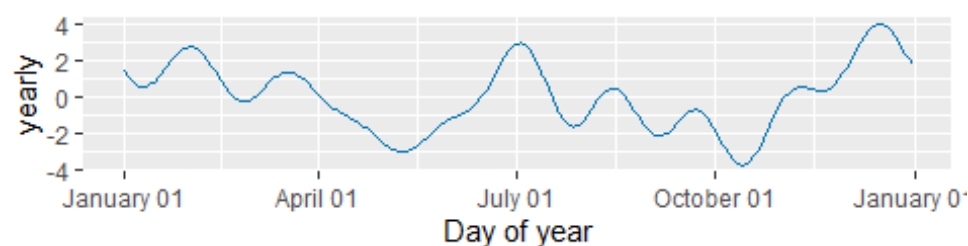
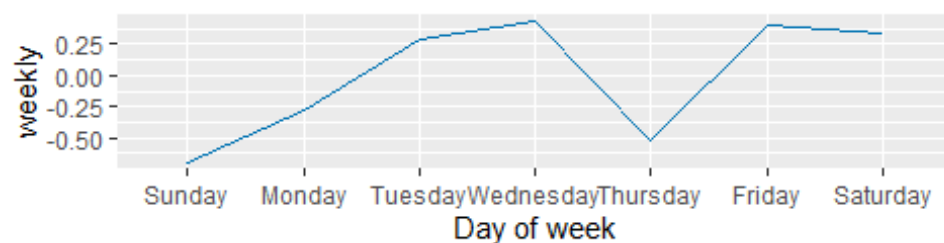
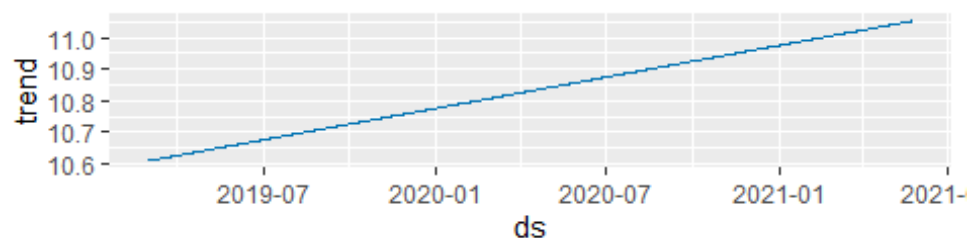
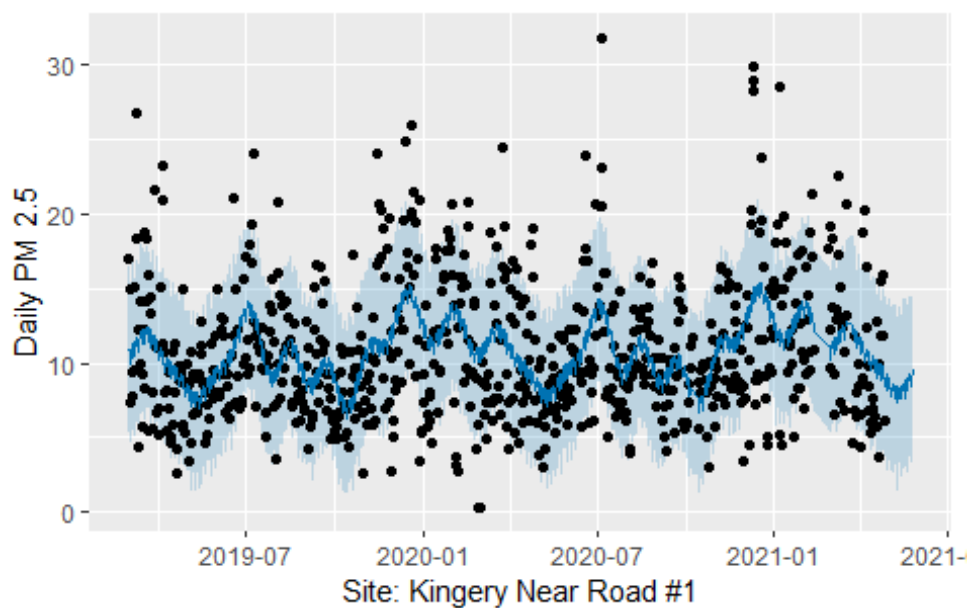
9430

## 6	2019-03-06	10.61281	0.7481957	0.7481957	0.748
1957					
##	weekly	weekly_lower	weekly_upper	yearly	yearly_lower yearly_upper
per					
## 1	0.4087580	0.4087580	0.4087580	-0.141148958	-0.141148958 -0.141148
958					
## 2	0.3421312	0.3421312	0.3421312	-0.077013484	-0.077013484 -0.077013
484					
## 3	-0.6900769	-0.6900769	-0.6900769	0.003200498	0.003200498 0.003200
498					
## 4	-0.2716181	-0.2716181	-0.2716181	0.097249602	0.097249602 0.097249
602					
## 5	0.2933013	0.2933013	0.2933013	0.202641691	0.202641691 0.202641
691					
## 6	0.4315047	0.4315047	0.4315047	0.316691023	0.316691023 0.316691
023					
##	multiplicative_terms multiplicative_terms_lower multiplicative_terms_upper				
## 1		0		0	
0					
## 2		0		0	
0					
## 3		0		0	
0					
## 4		0		0	
0					
## 5		0		0	
0					
## 6		0		0	
0					
##	yhat_lower	yhat_upper	trend_lower	trend_upper	yhat
## 1	5.463317	16.52915	10.61011	10.61011	10.877716
## 2	5.165759	16.34942	10.61065	10.61065	10.875766
## 3	4.711470	15.37910	10.61119	10.61119	9.924313
## 4	4.920916	16.26428	10.61173	10.61173	10.437363
## 5	5.528562	16.70107	10.61227	10.61227	11.108215
## 6	5.813670	16.78566	10.61281	10.61281	11.361010
##	ds	trend	additive_terms	additive_terms_lower	
## 782	2021-05-20	11.05001	-2.836649	-2.836649	
## 783	2021-05-21	11.05055	-1.800699	-1.800699	
## 784	2021-05-22	11.05110	-1.753295	-1.753295	
## 785	2021-05-23	11.05164	-2.672434	-2.672434	
## 786	2021-05-24	11.05218	-2.143519	-2.143519	
## 787	2021-05-25	11.05273	-1.472211	-1.472211	
##	additive_terms_upper	weekly	weekly_lower	weekly_upper	yearly
## 782	-2.836649	-0.5140003	-0.5140003	-0.5140003	-2.322649
## 783	-1.800699	0.4087580	0.4087580	0.4087580	-2.209457
## 784	-1.753295	0.3421312	0.3421312	0.3421312	-2.095426
## 785	-2.672434	-0.6900769	-0.6900769	-0.6900769	-1.982357
## 786	-2.143519	-0.2716181	-0.2716181	-0.2716181	-1.871901
## 787	-1.472211	0.2933013	0.2933013	0.2933013	-1.765512
##	yearly_lower	yearly_upper	multiplicative_terms	multiplicative_terms_lo	wer


```

## 782      -2.322649      -2.322649              0
0
## 783      -2.209457      -2.209457              0
0
## 784      -2.095426      -2.095426              0
0
## 785      -1.982357      -1.982357              0
0
## 786      -1.871901      -1.871901              0
0
## 787      -1.765512      -1.765512              0
0
##      multiplicative_terms_upper yhat_lower yhat_upper trend_lower trend_upper
er
## 782              0  2.564483   13.91118   11.05001   11.050
01
## 783              0  3.982977   14.80147   11.05055   11.050
55
## 784              0  3.846859   14.60079   11.05110   11.051
10
## 785              0  2.965025   13.50830   11.05164   11.051
64
## 786              0  3.275989   14.45883   11.05218   11.052
18
## 787              0  3.714750   15.11082   11.05273   11.052
73
##      yhat
## 782 8.213361
## 783 9.249854
## 784 9.297801
## 785 8.379206
## 786 8.908664
## 787 9.580515

```



[1] "Forecast for the Site: LIBERTY SCHOOL"

##	ds	trend	additive_terms	additive_terms_lower	additive_terms_upper
## 1	2018-01-01	9.202497	1.0018492	1.0018492	1.0018492
## 2	2018-01-02	9.205501	1.0724347	1.0724347	1.0724347
## 3	2018-01-03	9.208504	1.0651032	1.0651032	1.0651032
## 4	2018-01-04	9.211508	0.9173477	0.9173477	0.9173477
## 5	2018-01-05	9.214512	1.1462511	1.1462511	1.1462511

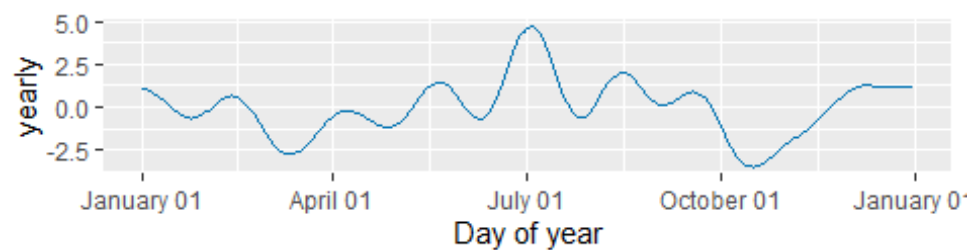
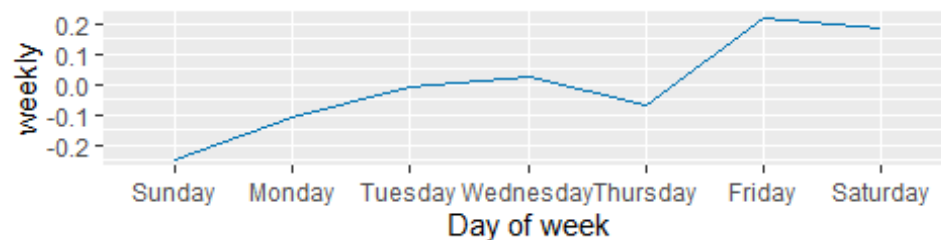
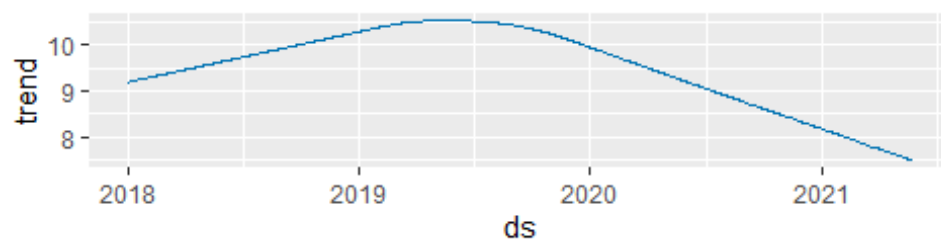
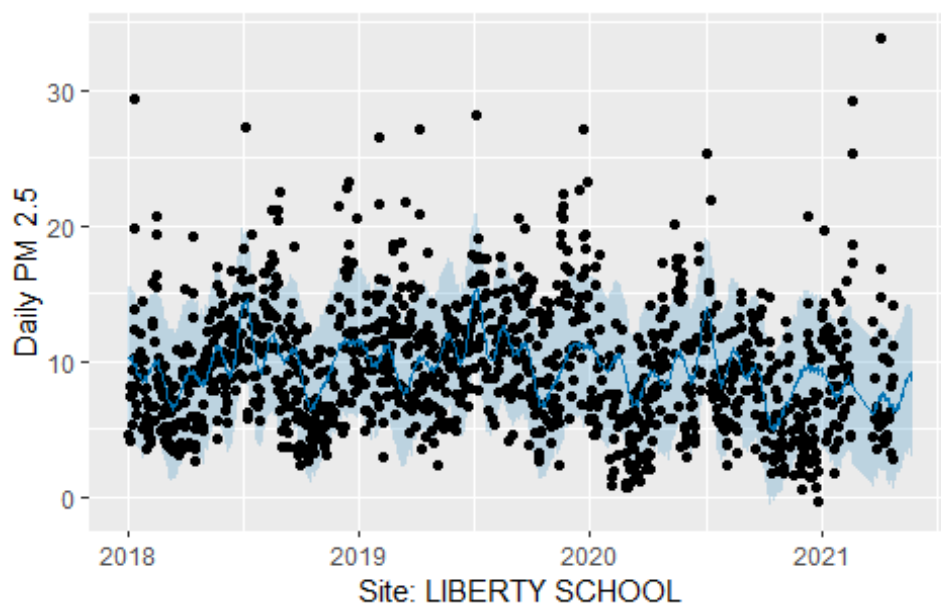
2511

## 6	2018-01-06	9.217515	1.0429169	1.0429169	1.042
9169					
##	weekly	weekly_lower	weekly_upper	yearly	yearly_lower yearly_upper
## 1	-0.107822247	-0.107822247	-0.107822247	1.1096714	1.1096714 1.1096714
## 2	-0.005785668	-0.005785668	-0.005785668	1.0782203	1.0782203 1.0782203
## 3	0.027351865	0.027351865	0.027351865	1.0377513	1.0377513 1.0377513
## 4	-0.070437471	-0.070437471	-0.070437471	0.9877852	0.9877852 0.9877852
## 5	0.218162454	0.218162454	0.218162454	0.9280886	0.9280886 0.9280886
## 6	0.184222037	0.184222037	0.184222037	0.8586949	0.8586949 0.8586949
##	multiplicative_terms	multiplicative_terms_lower	multiplicative_terms_upper		
## 1		0		0	
## 2		0		0	
## 3		0		0	
## 4		0		0	
## 5		0		0	
## 6		0		0	
##	yhat_lower	yhat_upper	trend_lower	trend_upper	yhat
## 1	4.970922	15.41905	9.202497	9.202497	10.20435
## 2	4.877122	15.43061	9.205501	9.205501	10.27794
## 3	4.714968	15.54369	9.208504	9.208504	10.27361
## 4	4.467813	15.52832	9.211508	9.211508	10.12886
## 5	4.761644	15.86253	9.214512	9.214512	10.36076
## 6	5.156897	15.83547	9.217515	9.217515	10.26043
##	ds	trend	additive_terms	additive_terms_lower	
## 1276	2021-05-20	7.514184	1.352501	1.352501	
## 1277	2021-05-21	7.509398	1.656342	1.656342	
## 1278	2021-05-22	7.504613	1.612301	1.612301	
## 1279	2021-05-23	7.499827	1.146919	1.146919	
## 1280	2021-05-24	7.495042	1.224501	1.224501	
## 1281	2021-05-25	7.490256	1.242572	1.242572	
##	additive_terms_upper	weekly	weekly_lower	weekly_upper	yearly
## 1276		1.352501	-0.070437471	-0.070437471	1.422938
## 1277		1.656342	0.218162454	0.218162454	1.438180
## 1278		1.612301	0.184222037	0.184222037	1.428079
## 1279		1.146919	-0.245690970	-0.245690970	1.392610
## 1280		1.224501	-0.107822247	-0.107822247	1.332324
## 1281		1.242572	-0.005785668	-0.005785668	1.248358
##	yearly_lower	yearly_upper	multiplicative_terms	multiplicative_terms_lower	

```

## 1276      1.422938      1.422938      0
0
## 1277      1.438180      1.438180      0
0
## 1278      1.428079      1.428079      0
0
## 1279      1.392610      1.392610      0
0
## 1280      1.332324      1.332324      0
0
## 1281      1.248358      1.248358      0
0
##      multiplicative_terms_upper yhat_lower yhat_upper trend_lower trend_up
per
## 1276      0      3.483585      14.16819      7.512304      7.516
901
## 1277      0      3.826361      14.79063      7.507259      7.512
412
## 1278      0      3.386043      14.79838      7.502231      7.507
867
## 1279      0      2.899663      14.01430      7.497054      7.503
493
## 1280      0      3.420059      13.84506      7.492092      7.498
914
## 1281      0      3.169261      13.99528      7.487015      7.494
360
##      yhat
## 1276 8.866685
## 1277 9.165740
## 1278 9.116914
## 1279 8.646747
## 1280 8.719543
## 1281 8.732828

```



[1] "Forecast for the Site: MAYFAIR PUMP STATION"

##	ds	trend	additive_terms	additive_terms_lower	additive_terms_upper
## 1	2018-01-05	9.450961	0.51881852	0.51881852	0.51881852
## 2	2018-01-08	9.451574	0.23432468	0.23432468	0.23432468
## 3	2018-01-09	9.451778	0.05180214	0.05180214	0.05180214
## 4	2018-01-13	9.452595	0.80382301	0.80382301	0.80382301
## 5	2018-01-14	9.452800	0.94574026	0.94574026	0.94574026

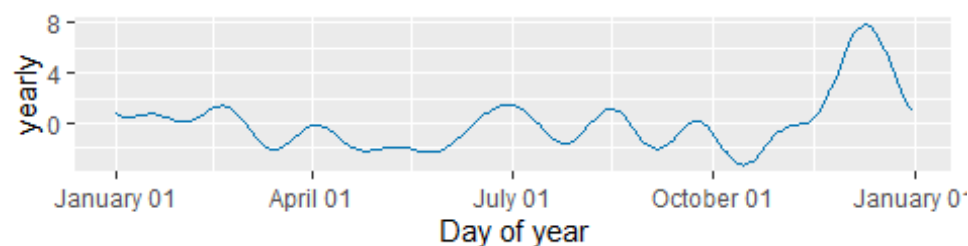
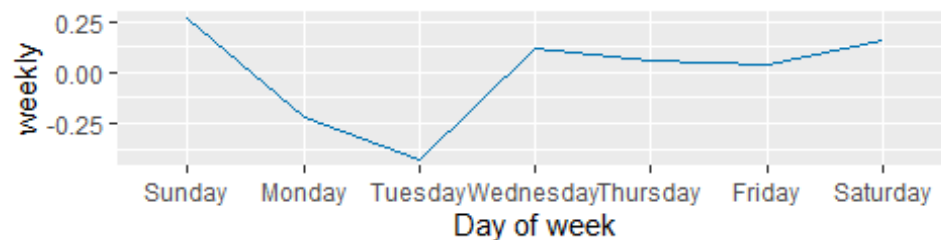
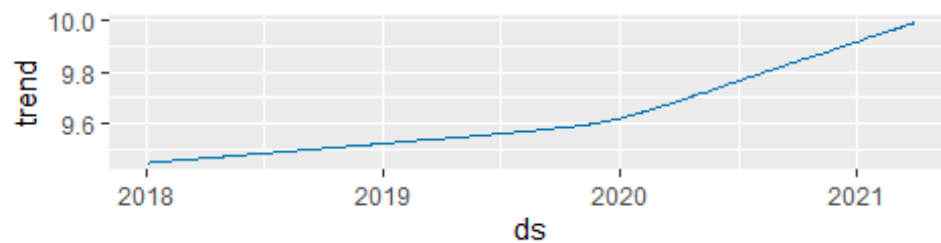
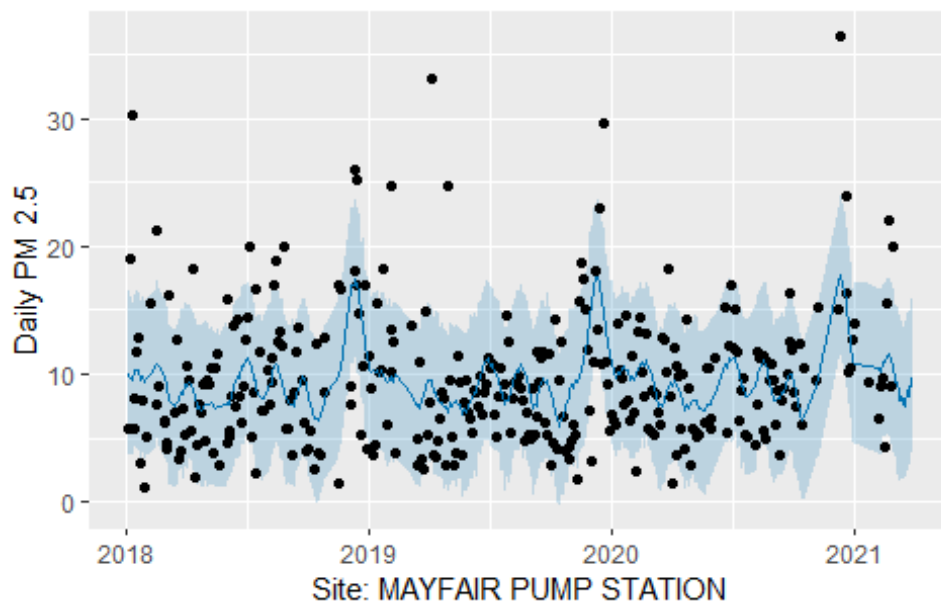
4026

```
## 6 2018-01-17 9.453413      0.86488012      0.86488012      0.8648
8012
##      weekly weekly_lower weekly_upper      yearly yearly_lower yearly_upper
## 1  0.0379512   0.0379512   0.0379512 0.4808673   0.4808673   0.4808673
## 2 -0.2151924  -0.2151924  -0.2151924 0.4495170   0.4495170   0.4495170
## 3 -0.4230195  -0.4230195  -0.4230195 0.4748216   0.4748216   0.4748216
## 4  0.1617983   0.1617983   0.1617983 0.6420247   0.6420247   0.6420247
## 5  0.2646769   0.2646769   0.2646769 0.6810634   0.6810634   0.6810634
## 6  0.1198450   0.1198450   0.1198450 0.7450351   0.7450351   0.7450351
##      multiplicative_terms multiplicative_terms_lower multiplicative_terms_upper
## 1      0      0
## 2      0      0
## 3      0      0
## 4      0      0
## 5      0      0
## 6      0      0
##      yhat_lower yhat_upper trend_lower trend_upper      yhat
## 1  3.901906   16.59605   9.450961   9.450961  9.969780
## 2  3.680712   16.11406   9.451574   9.451574  9.685899
## 3  3.708489   15.52448   9.451778   9.451778  9.503580
## 4  3.998554   16.41094   9.452595   9.452595 10.256418
## 5  4.454982   16.16692   9.452800   9.452800 10.398540
## 6  4.115515   16.54367   9.453413   9.453413 10.318293
##      ds      trend additive_terms additive_terms_lower
## 351 2021-03-24 9.984729   -0.9593901   -0.9593901
## 352 2021-03-25 9.985557   -0.8690028   -0.8690028
## 353 2021-03-26 9.986386   -0.7346267   -0.7346267
## 354 2021-03-27 9.987214   -0.4701711   -0.4701711
## 355 2021-03-28 9.988042   -0.2399448   -0.2399448
## 356 2021-03-29 9.988871   -0.6088231   -0.6088231
##      additive_terms_upper      weekly weekly_lower weekly_upper      yearly
## 351   -0.9593901  0.11984498  0.11984498  0.11984498 -1.0792351
## 352   -0.8690028  0.05394047  0.05394047  0.05394047 -0.9229432
## 353   -0.7346267  0.03795120  0.03795120  0.03795120 -0.7725779
## 354   -0.4701711  0.16179832  0.16179832  0.16179832 -0.6319694
## 355   -0.2399448  0.26467686  0.26467686  0.26467686 -0.5046216
## 356   -0.6088231 -0.21519236 -0.21519236 -0.21519236 -0.3936308
##      yearly_lower yearly_upper multiplicative_terms multiplicative_terms_lower
## 351  -1.0792351  -1.0792351      0
## 352  -0.9229432  -0.9229432      0
## 353  -0.7725779  -0.7725779      0
## 354  -0.6319694  -0.6319694      0
```

```

0
## 355 -0.5046216 -0.5046216 0
0
## 356 -0.3936308 -0.3936308 0
0
## multiplicative_terms_upper yhat_lower yhat_upper trend_lower trend_upper
er
## 351 0 3.016097 14.97686 9.984492 9.9849
21
## 352 0 2.640805 15.50520 9.985300 9.9857
79
## 353 0 3.068121 15.20290 9.986099 9.9866
24
## 354 0 3.236451 15.46026 9.986899 9.9874
69
## 355 0 3.918205 15.94244 9.987698 9.9883
13
## 356 0 2.957481 15.17526 9.988490 9.9891
61
## yhat
## 351 9.025339
## 352 9.116554
## 353 9.251759
## 354 9.517043
## 355 9.748098
## 356 9.380048

```



```
## [1] "Forecast for the Site: NORTHBROOK WATER PLANT"
##           ds      trend additive_terms additive_terms_lower additive_terms_u
pper
## 1 2018-01-01 8.593637    1.7250587      1.7250587      1.725
0587
## 2 2018-01-02 8.593843    1.0953208      1.0953208      1.095
3208
## 3 2018-01-02 8.593843    1.0953208      1.0953208      1.095
3208
## 4 2018-01-03 8.594048    1.1991766      1.1991766      1.199
1766
## 5 2018-01-04 8.594254    0.9335685      0.9335685      0.933
```

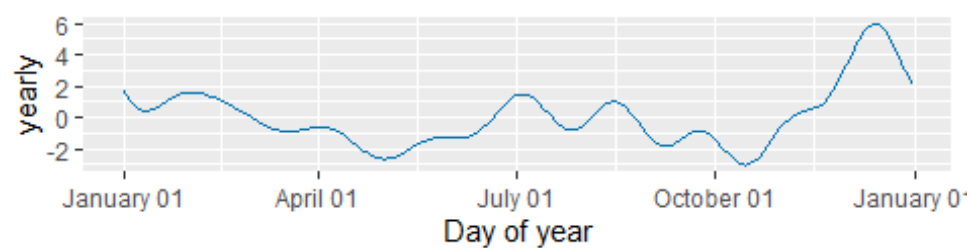
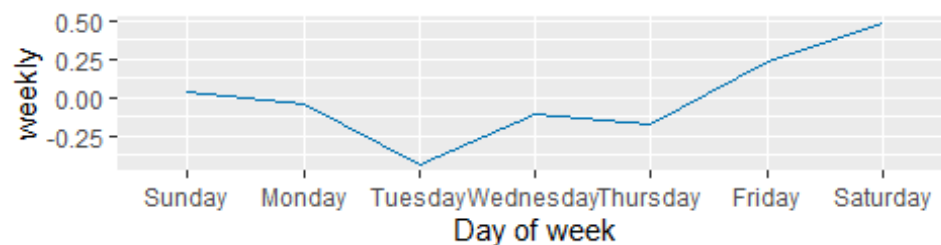
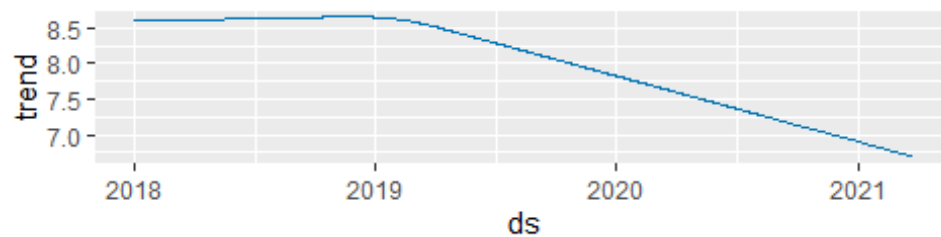
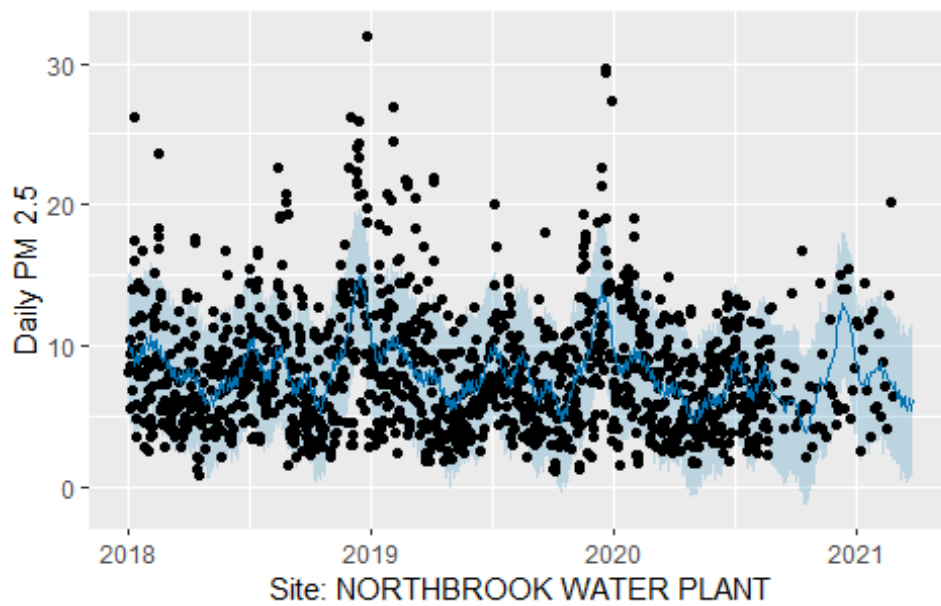

5685

```
## 6 2018-01-05 8.594459      1.1559055      1.1559055      1.155
9055
##      weekly weekly_lower weekly_upper      yearly yearly_lower yearly_upper
r
## 1 -0.04634822 -0.04634822 -0.04634822 1.7714069      1.7714069      1.771406
9
## 2 -0.43079608 -0.43079608 -0.43079608 1.5261168      1.5261168      1.526116
8
## 3 -0.43079608 -0.43079608 -0.43079608 1.5261168      1.5261168      1.526116
8
## 4 -0.10332413 -0.10332413 -0.10332413 1.3025007      1.3025007      1.302500
7
## 5 -0.16889516 -0.16889516 -0.16889516 1.1024636      1.1024636      1.102463
6
## 6  0.22849028  0.22849028  0.22849028 0.9274152      0.9274152      0.927415
2
##      multiplicative_terms multiplicative_terms_lower multiplicative_terms_upper
er
## 1              0              0
0
## 2              0              0
0
## 3              0              0
0
## 4              0              0
0
## 5              0              0
0
## 6              0              0
0
##      yhat_lower yhat_upper trend_lower trend_upper      yhat
## 1  5.072419    15.11446    8.593637    8.593637 10.318696
## 2  4.331781    14.91962    8.593843    8.593843  9.689163
## 3  4.476811    14.79971    8.593843    8.593843  9.689163
## 4  4.750760    15.08499    8.594048    8.594048  9.793225
## 5  4.617161    15.12971    8.594254    8.594254  9.527822
## 6  4.473801    15.20724    8.594459    8.594459  9.750364
##      ds      trend additive_terms additive_terms_lower
## 1338 2021-03-21 6.703953      -0.8430022      -0.8430022
## 1339 2021-03-22 6.701437      -0.9070292      -0.9070292
## 1340 2021-03-23 6.698921      -1.2660833      -1.2660833
## 1341 2021-03-24 6.696405      -0.9101265      -0.9101265
## 1342 2021-03-25 6.693888      -0.9452490      -0.9452490
## 1343 2021-03-26 6.691372      -0.5166440      -0.5166440
##      additive_terms_upper      weekly weekly_lower weekly_upper      yearly
## 1338      -0.8430022 0.03894109 0.03894109 0.03894109 -0.8819433
## 1339      -0.9070292 -0.04634822 -0.04634822 -0.04634822 -0.8606809
## 1340      -1.2660833 -0.43079608 -0.43079608 -0.43079608 -0.8352872
## 1341      -0.9101265 -0.10332413 -0.10332413 -0.10332413 -0.8068024
## 1342      -0.9452490 -0.16889516 -0.16889516 -0.16889516 -0.7763538
## 1343      -0.5166440 0.22849028 0.22849028 0.22849028 -0.7451343
##      yearly_lower yearly_upper multiplicative_terms multiplicative_terms_l
ower
```

```

## 1338    -0.8819433    -0.8819433                0
0
## 1339    -0.8606809    -0.8606809                0
0
## 1340    -0.8352872    -0.8352872                0
0
## 1341    -0.8068024    -0.8068024                0
0
## 1342    -0.7763538    -0.7763538                0
0
## 1343    -0.7451343    -0.7451343                0
0
##      multiplicative_terms_upper yhat_lower yhat_upper trend_lower trend_up
per
## 1338                0  0.6462433    11.29686    6.703110    6.704
849
## 1339                0  0.5051314    10.84805    6.700509    6.702
394
## 1340                0  0.1081362    10.68355    6.697879    6.699
945
## 1341                0  0.7062359    11.03437    6.695277    6.697
574
## 1342                0  0.6928889    11.45456    6.692697    6.695
123
## 1343                0  1.3519109    11.40498    6.690059    6.692
646
##      yhat
## 1338 5.860951
## 1339 5.794408
## 1340 5.432838
## 1341 5.786278
## 1342 5.748639
## 1343 6.174728

```



```
## [1] "Forecast for the Site: REGIONAL OFFICE BUILDING"
##           ds      trend additive_terms additive_terms_lower additive_terms_u
pper
## 1 2018-01-01 11.09605      0.9608434      0.9608434      0.960
8434
## 2 2018-01-02 11.09327      0.9392503      0.9392503      0.939
2503
## 3 2018-01-03 11.09049      1.4743646      1.4743646      1.474
3646
## 4 2018-01-04 11.08772      1.1181464      1.1181464      1.118
1464
## 5 2018-01-05 11.08494      0.8644932      0.8644932      0.864
```

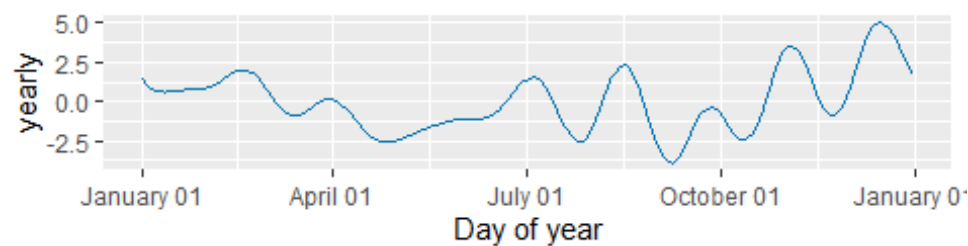
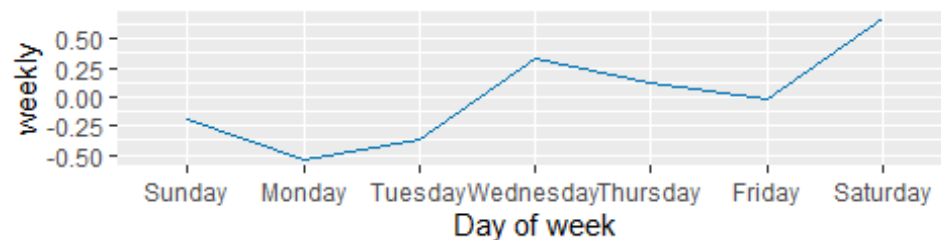
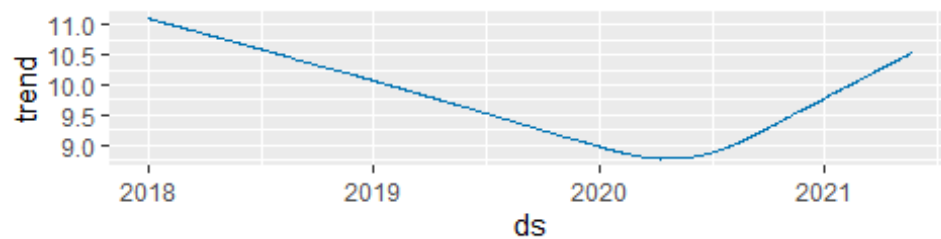
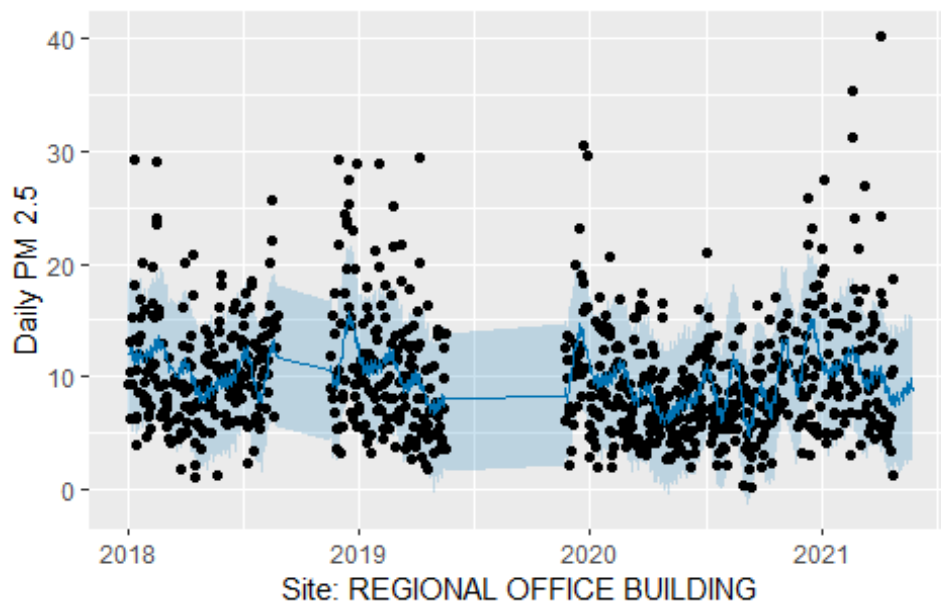
4932

## 6	2018-01-06	11.08216	1.4647545	1.4647545	1.4647545	1.4647545
##	weekly	weekly_lower	weekly_upper	yearly	yearly_lower	yearly_upper
## 1	-0.53245206	-0.53245206	-0.53245206	1.4932955	1.4932955	1.4932955
## 2	-0.36648760	-0.36648760	-0.36648760	1.3057379	1.3057379	1.3057379
## 3	0.33256215	0.33256215	0.33256215	1.1418025	1.1418025	1.1418025
## 4	0.11627810	0.11627810	0.11627810	1.0018683	1.0018683	1.0018683
## 5	-0.02117092	-0.02117092	-0.02117092	0.8856641	0.8856641	0.8856641
## 6	0.67242848	0.67242848	0.67242848	0.7923260	0.7923260	0.7923260
##	multiplicative_terms	multiplicative_terms_lower	multiplicative_terms_upper			
## 1		0		0		
## 2		0		0		
## 3		0		0		
## 4		0		0		
## 5		0		0		
## 6		0		0		
##	yhat_lower	yhat_upper	trend_lower	trend_upper	yhat	
## 1	6.139240	18.37889	11.09605	11.09605	12.05690	
## 2	5.668040	18.57194	11.09327	11.09327	12.03252	
## 3	5.991328	18.98775	11.09049	11.09049	12.56486	
## 4	6.380497	18.83925	11.08772	11.08772	12.20586	
## 5	5.588164	18.29649	11.08494	11.08494	11.94943	
## 6	6.323430	18.79056	11.08216	11.08216	12.54691	
##	ds	trend	additive_terms	additive_terms_lower		
## 919	2021-05-20	10.52231	-1.3654568	-1.3654568		
## 920	2021-05-21	10.52766	-1.4571267	-1.4571267		
## 921	2021-05-22	10.53301	-0.7195816	-0.7195816		
## 922	2021-05-23	10.53836	-1.5513951	-1.5513951		
## 923	2021-05-24	10.54372	-1.8434571	-1.8434571		
## 924	2021-05-25	10.54907	-1.6411811	-1.6411811		
##	additive_terms_upper	weekly	weekly_lower	weekly_upper	yearly	
## 919	-1.3654568	0.11627810	0.11627810	0.11627810	-1.481735	
## 920	-1.4571267	-0.02117092	-0.02117092	-0.02117092	-1.435956	
## 921	-0.7195816	0.67242848	0.67242848	0.67242848	-1.392010	
## 922	-1.5513951	-0.20115815	-0.20115815	-0.20115815	-1.350237	
## 923	-1.8434571	-0.53245206	-0.53245206	-0.53245206	-1.311005	
## 924	-1.6411811	-0.36648760	-0.36648760	-0.36648760	-1.274693	
##	yearly_lower	yearly_upper	multiplicative_terms	multiplicative_terms_lower		

```

## 919      -1.481735      -1.481735              0
0
## 920      -1.435956      -1.435956              0
0
## 921      -1.392010      -1.392010              0
0
## 922      -1.350237      -1.350237              0
0
## 923      -1.311005      -1.311005              0
0
## 924      -1.274693      -1.274693              0
0
##      multiplicative_terms_upper yhat_lower yhat_upper trend_lower trend_upper
er
## 919              0      2.483391      15.48285      10.51975      10.524
69
## 920              0      2.534521      15.47333      10.52472      10.530
37
## 921              0      3.852787      16.29010      10.52970      10.535
95
## 922              0      2.552147      15.41951      10.53471      10.541
61
## 923              0      2.703396      15.23921      10.53983      10.547
28
## 924              0      2.314869      15.24549      10.54487      10.552
98
##      yhat
## 919 9.156857
## 920 9.070537
## 921 9.813433
## 922 8.986970
## 923 8.700258
## 924 8.907885

```



[1] "Forecast for the Site: SPRINGFIELD PUMP STATION"

##	ds	trend	additive_terms	additive_terms_lower	additive_terms_upper
## 1	2018-01-01	8.365814	0.23973506	0.23973506	0.23973506
## 2	2018-01-02	8.367742	0.08832429	0.08832429	0.08832429
## 3	2018-01-02	8.367742	0.08832429	0.08832429	0.08832429
## 4	2018-01-03	8.369669	0.25869716	0.25869716	0.25869716
## 5	2018-01-04	8.371597	0.10084110	0.10084110	0.10084110

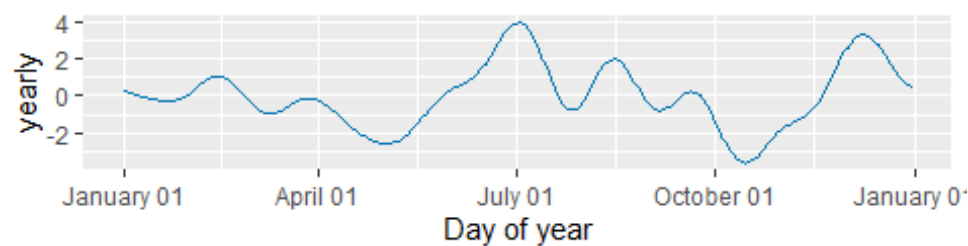
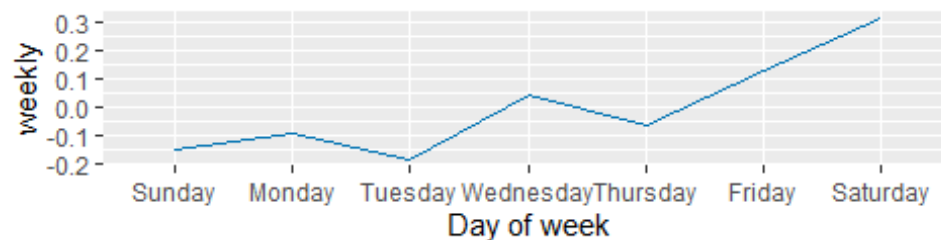
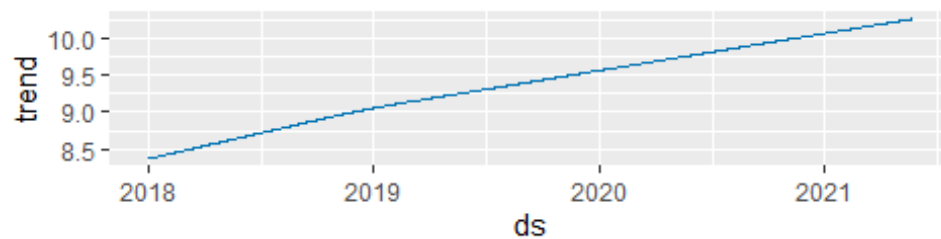
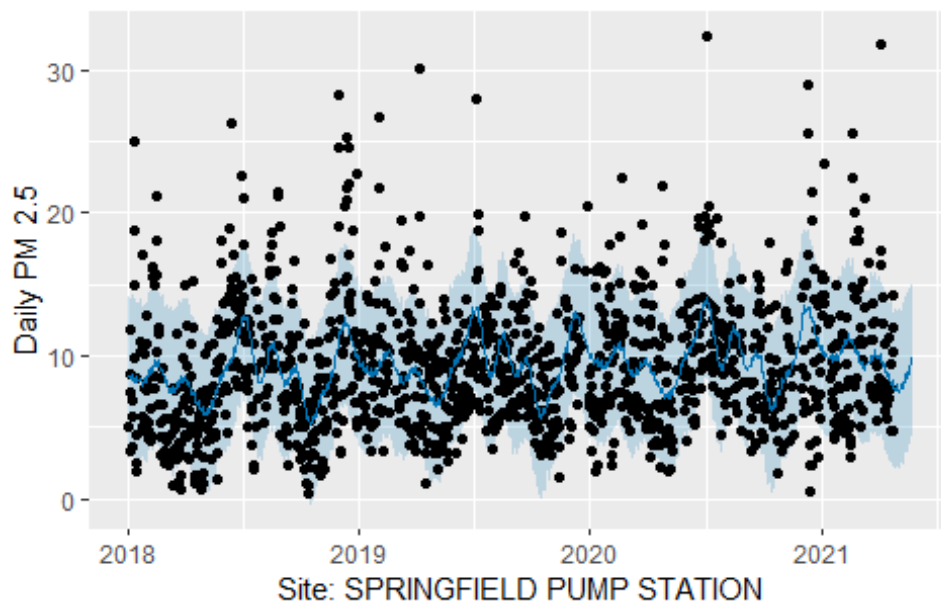
4110

```
## 6 2018-01-05 8.373524      0.25283804      0.25283804      0.2528
3804
##      weekly weekly_lower weekly_upper      yearly yearly_lower yearly_upper
r
## 1 -0.09197834 -0.09197834 -0.09197834 0.3317134      0.3317134      0.331713
4
## 2 -0.17989841 -0.17989841 -0.17989841 0.2682227      0.2682227      0.268222
7
## 3 -0.17989841 -0.17989841 -0.17989841 0.2682227      0.2682227      0.268222
7
## 4  0.04564617  0.04564617  0.04564617 0.2130510      0.2130510      0.213051
0
## 5 -0.06416499 -0.06416499 -0.06416499 0.1650061      0.1650061      0.165006
1
## 6  0.12998679  0.12998679  0.12998679 0.1228513      0.1228513      0.122851
3
##      multiplicative_terms multiplicative_terms_lower multiplicative_terms_upper
## 1
0
## 2
0
## 3
0
## 4
0
## 5
0
## 6
0
##      yhat_lower yhat_upper trend_lower trend_upper      yhat
## 1  2.854135      14.09298      8.365814      8.365814 8.605549
## 2  2.577219      14.14246      8.367742      8.367742 8.456066
## 3  3.444412      14.24587      8.367742      8.367742 8.456066
## 4  3.545850      13.86581      8.369669      8.369669 8.628366
## 5  3.154265      14.04388      8.371597      8.371597 8.472438
## 6  3.380274      13.91255      8.373524      8.373524 8.626362
##      ds      trend additive_terms additive_terms_lower
## 1308 2021-05-20 10.26362      -1.1094390      -1.1094390
## 1309 2021-05-21 10.26500      -0.7725540      -0.7725540
## 1310 2021-05-22 10.26638      -0.4523987      -0.4523987
## 1311 2021-05-23 10.26777      -0.7741671      -0.7741671
## 1312 2021-05-24 10.26915      -0.5848525      -0.5848525
## 1313 2021-05-25 10.27054      -0.5466328      -0.5466328
##      additive_terms_upper      weekly weekly_lower weekly_upper      yearly
## 1308      -1.1094390 -0.06416499 -0.06416499 -0.06416499 -1.0452741
## 1309      -0.7725540 0.12998679 0.12998679 0.12998679 -0.9025408
## 1310      -0.4523987 0.30958027 0.30958027 0.30958027 -0.7619789
## 1311      -0.7741671 -0.14917149 -0.14917149 -0.14917149 -0.6249956
## 1312      -0.5848525 -0.09197834 -0.09197834 -0.09197834 -0.4928742
## 1313      -0.5466328 -0.17989841 -0.17989841 -0.17989841 -0.3667344
##      yearly_lower yearly_upper multiplicative_terms multiplicative_terms_l
ower
```

```

## 1308    -1.0452741    -1.0452741                0
0
## 1309    -0.9025408    -0.9025408                0
0
## 1310    -0.7619789    -0.7619789                0
0
## 1311    -0.6249956    -0.6249956                0
0
## 1312    -0.4928742    -0.4928742                0
0
## 1313    -0.3667344    -0.3667344                0
0
##          multiplicative_terms_upper yhat_lower yhat_upper trend_lower trend_up
per
## 1308                                0    3.711507    14.63015    10.26340    10.26
375
## 1309                                0    3.985810    15.11505    10.26476    10.26
516
## 1310                                0    4.240771    15.26559    10.26612    10.26
656
## 1311                                0    4.420020    14.96674    10.26749    10.26
796
## 1312                                0    3.865778    15.03563    10.26885    10.26
936
## 1313                                0    4.083499    15.20087    10.27022    10.27
076
##          yhat
## 1308 9.154179
## 1309 9.492447
## 1310 9.813986
## 1311 9.493601
## 1312 9.684299
## 1313 9.723902

```

```
## [1] "Forecast for the Site: VILLAGE GARAGE"
##           ds      trend additive_terms additive_terms_lower additive_terms_u
pper
## 1 2018-01-01 8.209327    0.2981019      0.2981019      0.298
1019
## 2 2018-01-02 8.213807    0.4105886      0.4105886      0.410
5886
## 3 2018-01-02 8.213807    0.4105886      0.4105886      0.410
5886
## 4 2018-01-03 8.218288    0.3746508      0.3746508      0.374
6508
## 5 2018-01-05 8.227248    0.4872932      0.4872932      0.487
```

2932

6 2018-01-06 8.231729 0.6963822 0.6963822 0.696

3822

weekly weekly_lower weekly_upper yearly yearly_lower yearly_upper

1 -0.17871126 -0.17871126 -0.17871126 0.4768131 0.4768131 0.476813

1

2 -0.04566417 -0.04566417 -0.04566417 0.4562528 0.4562528 0.456252

8

3 -0.04566417 -0.04566417 -0.04566417 0.4562528 0.4562528 0.456252

8

4 -0.06909002 -0.06909002 -0.06909002 0.4437408 0.4437408 0.443740

8

5 0.04966539 0.04966539 0.04966539 0.4376278 0.4376278 0.437627

8

6 0.25514829 0.25514829 0.25514829 0.4412340 0.4412340 0.441234

0

multiplicative_terms multiplicative_terms_lower multiplicative_terms_upper

1 0 0

0

2 0 0

0

3 0 0

0

4 0 0

0

5 0 0

0

6 0 0

0

yhat_lower yhat_upper trend_lower trend_upper yhat

1 2.996191 13.81626 8.209327 8.209327 8.507429

2 3.590083 13.62176 8.213807 8.213807 8.624396

3 3.732038 13.89599 8.213807 8.213807 8.624396

4 3.729236 13.22256 8.218288 8.218288 8.592938

5 3.893134 13.68629 8.227248 8.227248 8.714542

6 3.794219 13.86927 8.231729 8.231729 8.928111

ds trend additive_terms additive_terms_lower

1214 2021-05-20 10.25854 -0.151299677 -0.151299677

1215 2021-05-21 10.26815 -0.132091435 -0.132091435

1216 2021-05-22 10.27777 0.143293299 0.143293299

1217 2021-05-23 10.28738 -0.171261207 -0.171261207

1218 2021-05-24 10.29699 -0.178274551 -0.178274551

1219 2021-05-25 10.30661 -0.003205851 -0.003205851

additive_terms_upper weekly weekly_lower weekly_upper yearly

1214 -0.151299677 0.10889142 0.10889142 0.10889142 -0.2601910

952

1215 -0.132091435 0.04966539 0.04966539 0.04966539 -0.1817568

263

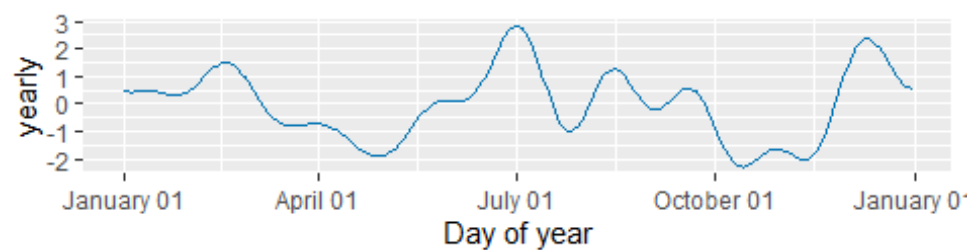
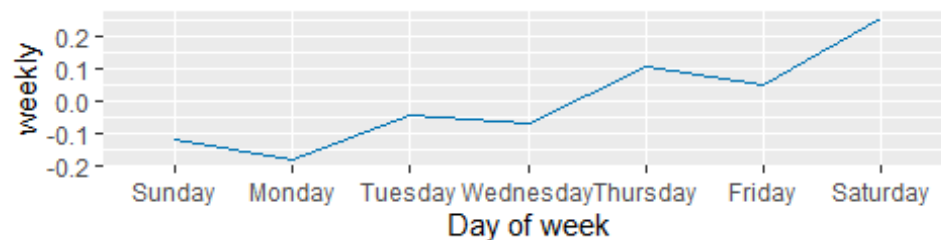
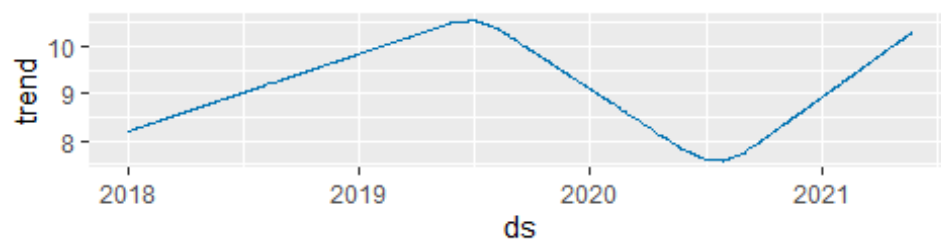
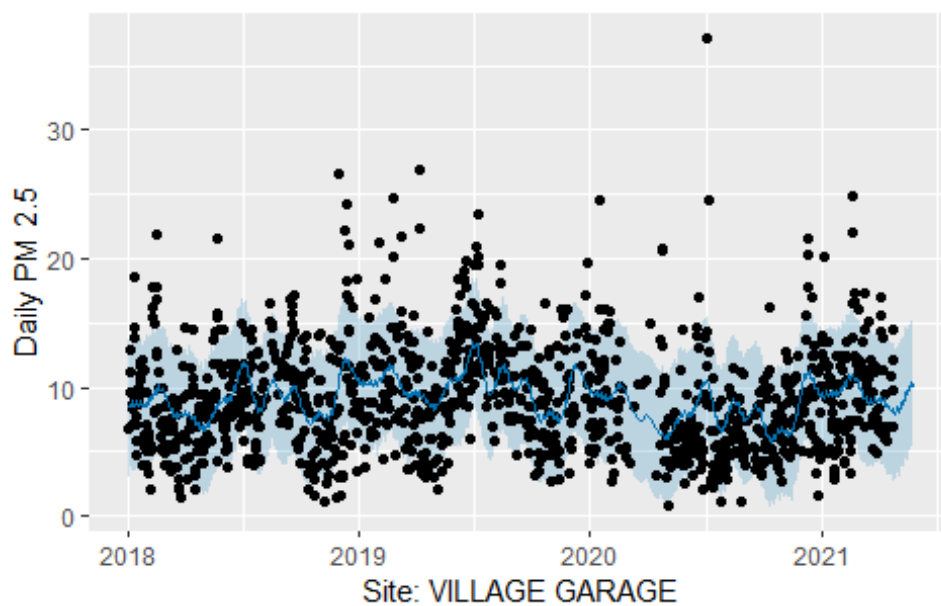
1216 0.143293299 0.25514829 0.25514829 0.25514829 -0.1118549

932

1217 -0.171261207 -0.12023965 -0.12023965 -0.12023965 -0.0510215

555

```
## 1218      -0.178274551 -0.17871126  -0.17871126  -0.17871126  0.0004367
111
## 1219      -0.003205851 -0.04566417  -0.04566417  -0.04566417  0.0424583
146
##      yearly_lower  yearly_upper multiplicative_terms
## 1214 -0.2601910952 -0.2601910952                0
## 1215 -0.1817568263 -0.1817568263                0
## 1216 -0.1118549932 -0.1118549932                0
## 1217 -0.0510215555 -0.0510215555                0
## 1218  0.0004367111  0.0004367111                0
## 1219  0.0424583146  0.0424583146                0
##      multiplicative_terms_lower multiplicative_terms_upper yhat_lower
## 1214                        0                        0  5.125644
## 1215                        0                        0  5.088286
## 1216                        0                        0  5.499998
## 1217                        0                        0  5.509220
## 1218                        0                        0  4.861307
## 1219                        0                        0  5.209475
##      yhat_upper trend_lower trend_upper      yhat
## 1214   14.84551   10.25037   10.26977 10.10724
## 1215   15.08022   10.25870   10.28038 10.13606
## 1216   15.67311   10.26742   10.29101 10.42106
## 1217   15.08119   10.27615   10.30174 10.11612
## 1218   15.28721   10.28430   10.31259 10.11872
## 1219   15.09044   10.29249   10.32427 10.30340
```



[1] "Forecast for the Site: VILLAGE HALL"

##	ds	trend	additive_terms	additive_terms_lower	additive_terms_upper
## 1	2018-01-02	9.806974	-0.4192561	-0.4192561	-0.4192561
## 2	2018-01-03	9.807098	0.1081321	0.1081321	0.1081321
## 3	2018-01-05	9.807348	0.5394176	0.5394176	0.5394176
## 4	2018-01-08	9.807721	1.9452314	1.9452314	1.9452314
## 5	2018-01-08	9.807721	1.9452314	1.9452314	1.9452314

2314

## 6	2018-01-11	9.808095	0.8821984	0.8821984	0.8821984	0.8821984
------	------------	----------	-----------	-----------	-----------	-----------

1984

##		weekly	weekly_lower	weekly_upper	yearly	yearly_lower	yearly_upper
----	--	--------	--------------	--------------	--------	--------------	--------------

r

## 1	-0.79676636	-0.79676636	-0.79676636	0.3775102	0.3775102	0.3775102
------	-------------	-------------	-------------	-----------	-----------	-----------

2

## 2	-0.22408871	-0.22408871	-0.22408871	0.3322208	0.3322208	0.3322208
------	-------------	-------------	-------------	-----------	-----------	-----------

8

## 3	0.20708540	0.20708540	0.20708540	0.3323322	0.3323322	0.3323322
------	------------	------------	------------	-----------	-----------	-----------

2

## 4	1.43487709	1.43487709	1.43487709	0.5103543	0.5103543	0.5103543
------	------------	------------	------------	-----------	-----------	-----------

3

## 5	1.43487709	1.43487709	1.43487709	0.5103543	0.5103543	0.5103543
------	------------	------------	------------	-----------	-----------	-----------

3

## 6	0.07435236	0.07435236	0.07435236	0.8078460	0.8078460	0.8078460
------	------------	------------	------------	-----------	-----------	-----------

0

##		multiplicative_terms	multiplicative_terms_lower	multiplicative_terms_upper
----	--	----------------------	----------------------------	----------------------------

er

## 1	0
------	---

0

## 2	0
------	---

0

## 3	0
------	---

0

## 4	0
------	---

0

## 5	0
------	---

0

## 6	0
------	---

0

##	yhat_lower	yhat_upper	trend_lower	trend_upper	yhat
----	------------	------------	-------------	-------------	------

## 1	3.921840	15.10777	9.806974	9.806974	9.387718
------	----------	----------	----------	----------	----------

## 2	4.110469	15.93259	9.807098	9.807098	9.915230
------	----------	----------	----------	----------	----------

## 3	4.820581	16.28746	9.807348	9.807348	10.346765
------	----------	----------	----------	----------	-----------

## 4	6.005696	17.52711	9.807721	9.807721	11.752953
------	----------	----------	----------	----------	-----------

## 5	5.974121	17.35614	9.807721	9.807721	11.752953
------	----------	----------	----------	----------	-----------

## 6	4.647436	16.44508	9.808095	9.808095	10.690294
------	----------	----------	----------	----------	-----------

##	ds	trend	additive_terms	additive_terms_lower
----	----	-------	----------------	----------------------

## 554	2021-03-24	9.843855	-0.81064459	-0.81064459
--------	------------	----------	-------------	-------------

## 555	2021-03-25	9.843868	-0.35982765	-0.35982765
--------	------------	----------	-------------	-------------

## 556	2021-03-26	9.843881	-0.09419901	-0.09419901
--------	------------	----------	-------------	-------------

## 557	2021-03-27	9.843893	-0.36835170	-0.36835170
--------	------------	----------	-------------	-------------

## 558	2021-03-28	9.843906	-0.62969024	-0.62969024
--------	------------	----------	-------------	-------------

## 559	2021-03-29	9.843919	1.37563325	1.37563325
--------	------------	----------	------------	------------

##	additive_terms_upper	weekly	weekly_lower	weekly_upper	yearly
----	----------------------	--------	--------------	--------------	--------

## 554	-0.81064459	-0.22408871	-0.22408871	-0.22408871	-0.58655588
--------	-------------	-------------	-------------	-------------	-------------

## 555	-0.35982765	0.07435236	0.07435236	0.07435236	-0.43418001
--------	-------------	------------	------------	------------	-------------

## 556	-0.09419901	0.20708540	0.20708540	0.20708540	-0.30128441
--------	-------------	------------	------------	------------	-------------

## 557	-0.36835170	-0.17621326	-0.17621326	-0.17621326	-0.19213844
--------	-------------	-------------	-------------	-------------	-------------

## 558	-0.62969024	-0.51924652	-0.51924652	-0.51924652	-0.11044372
--------	-------------	-------------	-------------	-------------	-------------

## 559	1.37563325	1.43487709	1.43487709	1.43487709	-0.05924385
--------	------------	------------	------------	------------	-------------

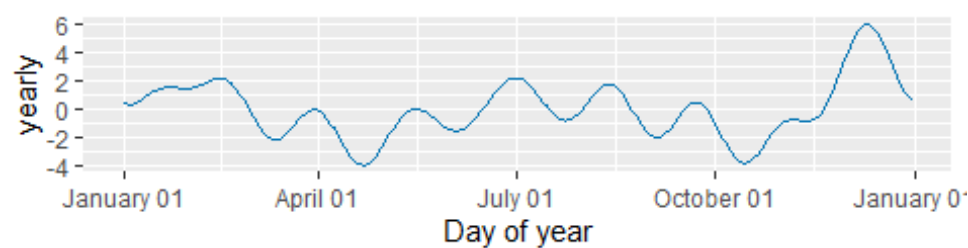
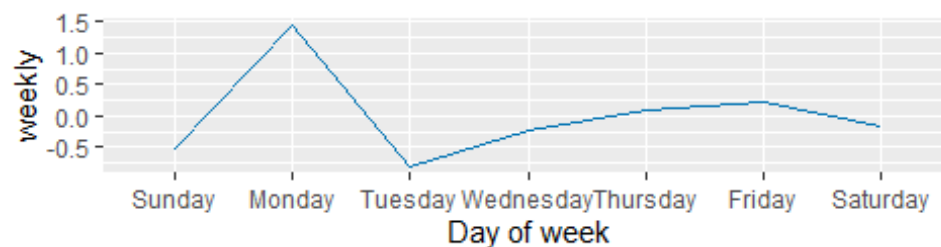
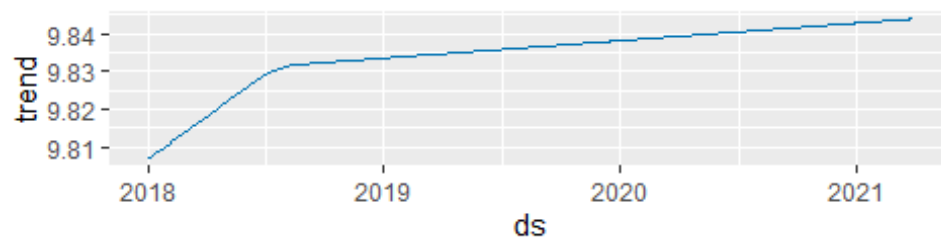
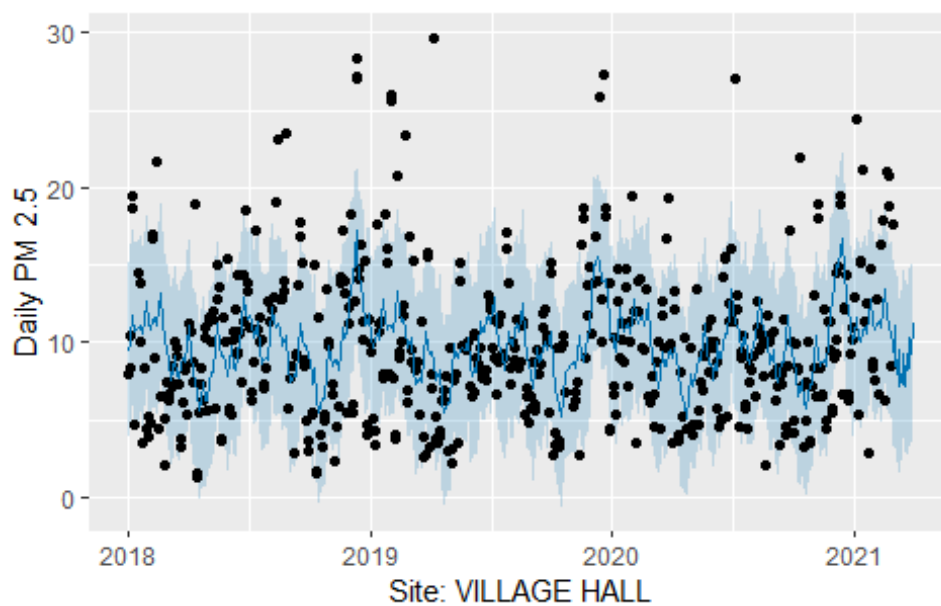
##	yearly_lower	yearly_upper	multiplicative_terms	multiplicative_terms_lower
----	--------------	--------------	----------------------	----------------------------

wer

```

## 554 -0.58655588 -0.58655588 0
0
## 555 -0.43418001 -0.43418001 0
0
## 556 -0.30128441 -0.30128441 0
0
## 557 -0.19213844 -0.19213844 0
0
## 558 -0.11044372 -0.11044372 0
0
## 559 -0.05924385 -0.05924385 0
0
##      multiplicative_terms_upper yhat_lower yhat_upper trend_lower trend_upper
er
## 554      0  3.262753  14.74741  9.843815  9.8438
77
## 555      0  4.077042  15.33098  9.843824  9.8438
94
## 556      0  3.756919  15.17164  9.843832  9.8439
09
## 557      0  4.356626  15.21504  9.843842  9.8439
28
## 558      0  3.488802  15.00089  9.843851  9.8439
44
## 559      0  5.576026  16.75127  9.843860  9.8439
61
##      yhat
## 554 9.033211
## 555 9.484040
## 556 9.749682
## 557 9.475542
## 558 9.214216
## 559 11.219552

```



[1] "Forecast for the Site: WASHINGTON HS"

##	ds	trend	additive_terms	additive_terms_lower	additive_terms_upper
## 1	2018-01-02	9.301248	0.8108945	0.8108945	0.8108945
## 2	2018-01-08	9.299628	2.3290231	2.3290231	2.3290231
## 3	2018-01-09	9.299358	1.1011033	1.1011033	1.1011033
## 4	2018-01-11	9.298818	1.3768543	1.3768543	1.3768543
## 5	2018-01-14	9.298008	1.4234772	1.4234772	1.4234772

4772

6 2018-01-14 9.298008 1.4234772 1.4234772 1.423

4772

##	weekly	weekly_lower	weekly_upper	yearly	yearly_lower	yearly_upper
## 1	-0.4383432	-0.4383432	-0.4383432	1.249238	1.249238	1.249238
## 2	0.8678148	0.8678148	0.8678148	1.461208	1.461208	1.461208
## 3	-0.4383432	-0.4383432	-0.4383432	1.539447	1.539447	1.539447
## 4	-0.3160987	-0.3160987	-0.3160987	1.692953	1.692953	1.692953
## 5	-0.4339957	-0.4339957	-0.4339957	1.857473	1.857473	1.857473
## 6	-0.4339957	-0.4339957	-0.4339957	1.857473	1.857473	1.857473
##	multiplicative_terms		multiplicative_terms_lower		multiplicative_terms_upper	

er

## 1	0	0
------	---	---

0

## 2	0	0
------	---	---

0

## 3	0	0
------	---	---

0

## 4	0	0
------	---	---

0

## 5	0	0
------	---	---

0

## 6	0	0
------	---	---

0

##	yhat_lower	yhat_upper	trend_lower	trend_upper	yhat
----	------------	------------	-------------	-------------	------

## 1	4.660887	15.47566	9.301248	9.301248	10.11214
------	----------	----------	----------	----------	----------

## 2	5.974755	17.25018	9.299628	9.299628	11.62865
------	----------	----------	----------	----------	----------

## 3	5.080666	16.53267	9.299358	9.299358	10.40046
------	----------	----------	----------	----------	----------

## 4	4.954660	15.98335	9.298818	9.298818	10.67567
------	----------	----------	----------	----------	----------

## 5	5.287214	16.56781	9.298008	9.298008	10.72149
------	----------	----------	----------	----------	----------

## 6	5.338330	16.44666	9.298008	9.298008	10.72149
------	----------	----------	----------	----------	----------

##	ds	trend	additive_terms	additive_terms_lower
----	----	-------	----------------	----------------------

## 472	2021-03-24	8.982548	-1.7862855	-1.7862855
--------	------------	----------	------------	------------

## 473	2021-03-25	8.982277	-1.8601906	-1.8601906
--------	------------	----------	------------	------------

## 474	2021-03-26	8.982006	-1.1805299	-1.1805299
--------	------------	----------	------------	------------

## 475	2021-03-27	8.981735	-1.1148866	-1.1148866
--------	------------	----------	------------	------------

## 476	2021-03-28	8.981464	-1.6438521	-1.6438521
--------	------------	----------	------------	------------

## 477	2021-03-29	8.981193	-0.2673778	-0.2673778
--------	------------	----------	------------	------------

##	additive_terms_upper	weekly	weekly_lower	weekly_upper	yearly
----	----------------------	--------	--------------	--------------	--------

## 472	-1.7862855	-0.1072635	-0.1072635	-0.1072635	-1.679022
--------	------------	------------	------------	------------	-----------

## 473	-1.8601906	-0.3160987	-0.3160987	-0.3160987	-1.544092
--------	------------	------------	------------	------------	-----------

## 474	-1.1805299	0.2374939	0.2374939	0.2374939	-1.418024
--------	------------	-----------	-----------	-----------	-----------

## 475	-1.1148866	0.1903924	0.1903924	0.1903924	-1.305279
--------	------------	-----------	-----------	-----------	-----------

## 476	-1.6438521	-0.4339957	-0.4339957	-0.4339957	-1.209856
--------	------------	------------	------------	------------	-----------

## 477	-0.2673778	0.8678148	0.8678148	0.8678148	-1.135193
--------	------------	-----------	-----------	-----------	-----------

##	yearly_lower	yearly_upper	multiplicative_terms	multiplicative_terms_lower
----	--------------	--------------	----------------------	----------------------------

## 472	-1.679022	-1.679022	0
--------	-----------	-----------	---

0

## 473	-1.544092	-1.544092	0
--------	-----------	-----------	---

0

## 474	-1.418024	-1.418024	0
--------	-----------	-----------	---

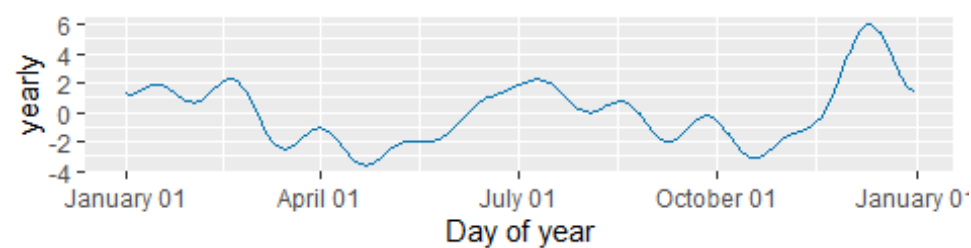
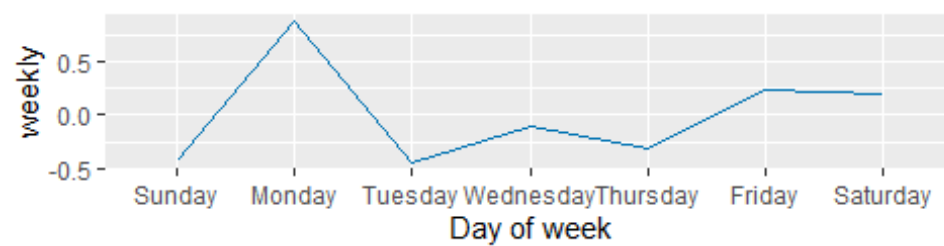
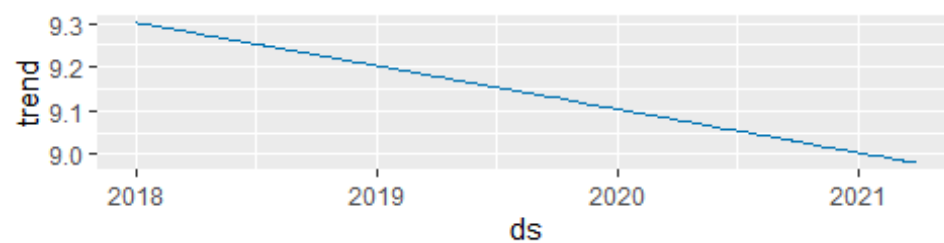
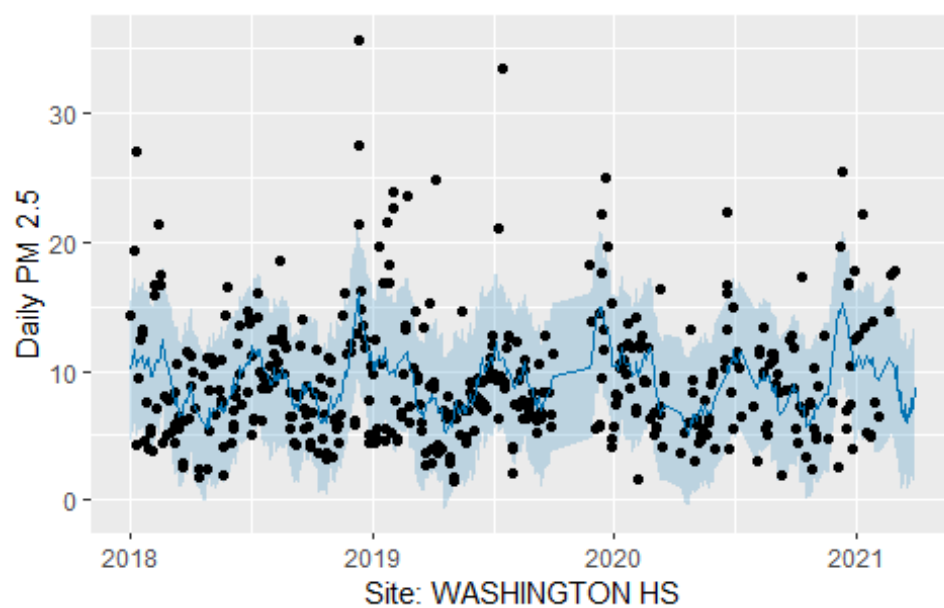
0

## 475	-1.305279	-1.305279	0
--------	-----------	-----------	---


```

0
## 476      -1.209856      -1.209856              0
0
## 477      -1.135193      -1.135193              0
0
##      multiplicative_terms_upper yhat_lower yhat_upper trend_lower trend_upper
er
## 472              0   1.965274   12.49929   8.982547   8.9825
48
## 473              0   1.551992   12.79731   8.982276   8.9822
77
## 474              0   2.083329   13.36569   8.982005   8.9820
06
## 475              0   2.350157   13.44027   8.981734   8.9817
35
## 476              0   1.433602   13.18236   8.981463   8.9814
64
## 477              0   2.891762   13.98937   8.981192   8.9811
93
##      yhat
## 472 7.196262
## 473 7.122086
## 474 7.801476
## 475 7.866848
## 476 7.337612
## 477 8.713815

```



Traffic

Traffic congestion load

Data structure

Here is the data structure.

```
## [1] 1048
## [1] 1048
## [1] 1830
## [1] 1832
## [1] 1873
## [1] 1864

## Classes 'data.table' and 'data.frame': 1852701 obs. of 8 variables:
## $ HOUR : int 17 17 17 17 17 17 17 17 17 17 ...
## $ DAY_OF_WEEK : int 4 4 4 4 4 4 4 4 4 4 ...
## $ MONTH : int 3 3 3 3 3 3 3 3 3 3 ...
## $ START_LATITUDE : num 41.9 41.9 41.9 41.9 42 ...
## $ START_LONGITUDE: num -87.7 -87.7 -87.8 -87.8 -87.8 ...
## $ END_LATITUDE : num 41.8 41.9 41.9 41.9 42 ...
## $ END_LONGITUDE : num -87.7 -87.7 -87.8 -87.8 -87.8 ...
## $ Date : IDate, format: "2018-03-21" "2018-03-21" ...
## - attr(*, ".internal.selfref")=<externalptr>

## HOUR DAY_OF_WEEK MONTH START_LATITUDE
## Min. : 0.00 Min. :1.000 Min. :2.000 Min. :41.66
## 1st Qu.: 8.00 1st Qu.:2.000 1st Qu.:3.000 1st Qu.:41.79
## Median :13.00 Median :4.000 Median :3.000 Median :41.85
## Mean :12.88 Mean :4.069 Mean :2.978 Mean :41.85
## 3rd Qu.:18.00 3rd Qu.:6.000 3rd Qu.:3.000 3rd Qu.:41.91
## Max. :23.00 Max. :7.000 Max. :3.000 Max. :42.01
## START_LONGITUDE END_LATITUDE END_LONGITUDE Date
## Min. :-87.84 Min. :41.66 Min. :-87.84 Min. :2018-02-28
## 1st Qu.: -87.72 1st Qu.:41.79 1st Qu.: -87.72 1st Qu.:2018-03-05
## Median : -87.67 Median :41.85 Median : -87.67 Median :2018-03-10
## Mean : -87.68 Mean :41.85 Mean : -87.68 Mean :2018-03-10
## 3rd Qu.: -87.63 3rd Qu.:41.91 3rd Qu.: -87.63 3rd Qu.:2018-03-16
## Max. : -87.54 Max. :42.01 Max. : -87.54 Max. :2018-03-21
```

Variable dictionary

Traffic cluster

We classify the congestion by its nearest pollution detection site. For this aim the matrix of starting and ending coordinates of was created, and the nearest neighboring site for every record was found. Then the data was grouped by the sites label and the number of records in every group was divided by the total number of rows. This way a relative measure of the mean traffic load for every of the sites was calculated.

```
length(c(dt$START_LONGITUDE, dt$END_LONGITUDE))
```

```

## [1] 3705402

length(c(dt$START_LATITUDE, dt$END_LATITUDE))

## [1] 3705402

#
congestions <-
  matrix(
    c(dt$START_LONGITUDE, dt$END_LONGITUDE, dt$START_LATITUDE, dt$END_LATITUDE), nrow = 2, ncol = 2*nrow(dt), byrow = TRUE)

congestions <- t(congestions)

xlim <- c(min(congestions[,1]), max(congestions[,1]))
ylim <- c(min(congestions[,2]), max(congestions[,2]))

centers <- matrix(c(site_obs$x, site_obs$y), nrow = 2, ncol = nrow(site_obs), byrow = TRUE)
centers <- t(centers)

row.names(centers) <- site_obs$Site_Name
zz <- NULL
for (j in 1:nrow(centers)) {
  z <- dissUtils::neighbors(congestions, matrix(centers[j,], nrow = 1))
  colnames(z) <- site_obs$Site_Name[j]
  zz <- cbind(zz, z)
}

z <- apply(zz, 1, function(x) colnames(zz)[which.min(x)])

traffic_load <- as.data.frame(table(z)/length(z))

colnames(traffic_load)[1] <- "Site_Name"

```

Traffic load on Chicago sites

```

traffic_load <- merge(site_obs, traffic_load, by = "Site_Name") # , by.y = "Site_Name"

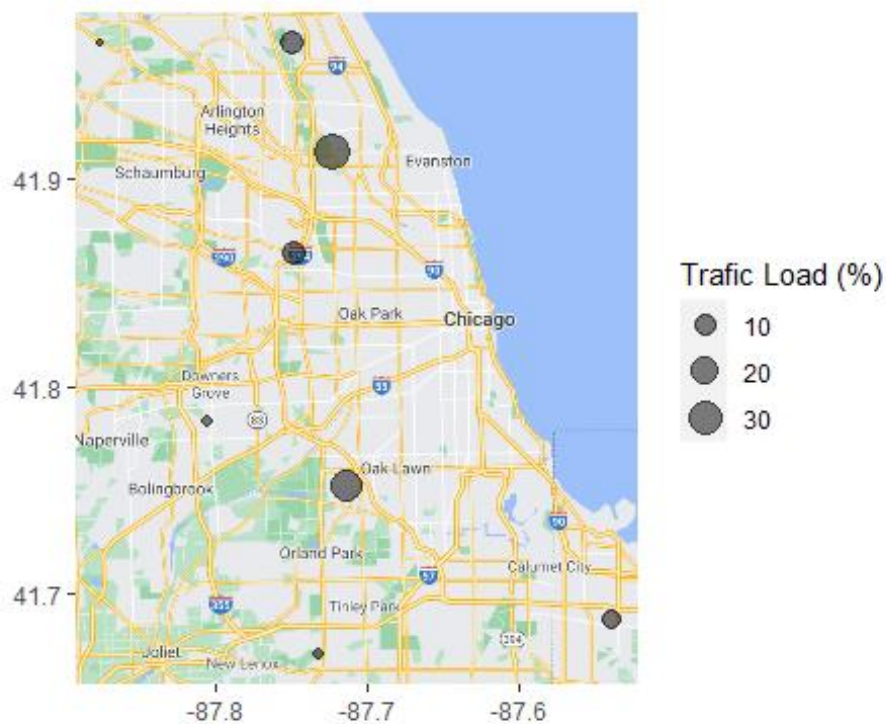
ggplot() +
  annotation_custom(rasterGrob(img, width = unit(1, "npc"), height = unit(1, "npc")), -Inf, Inf, -Inf, Inf) +
  geom_point(
    aes(
      x = as.numeric(x),
      y = as.numeric(y),
      size = as.numeric(Freq)*100
    ),
    data = traffic_load,
    alpha = 0.5,
    col = "black"
  ) +
  labs(
    x = "",

```

```

y = "",
size = "Traffic Load (%)"
) + theme(aspect.ratio=aspect.ratio )

```



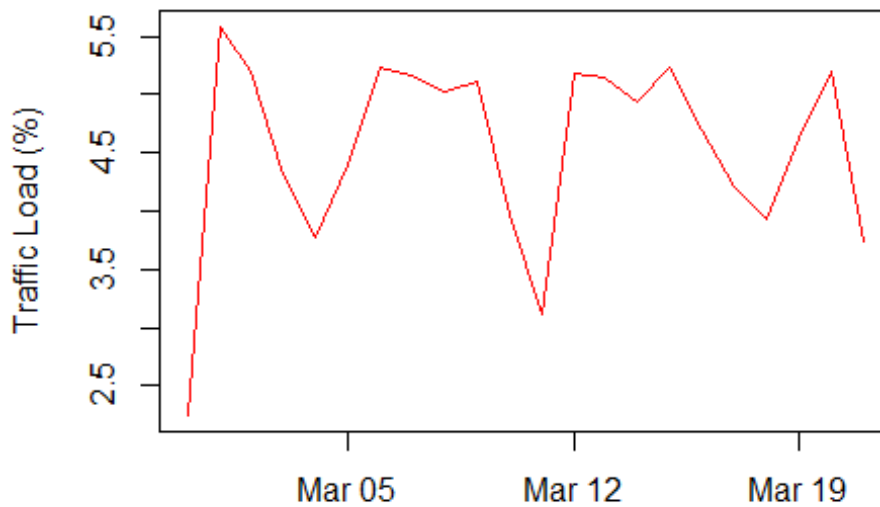
Traffic trends

```

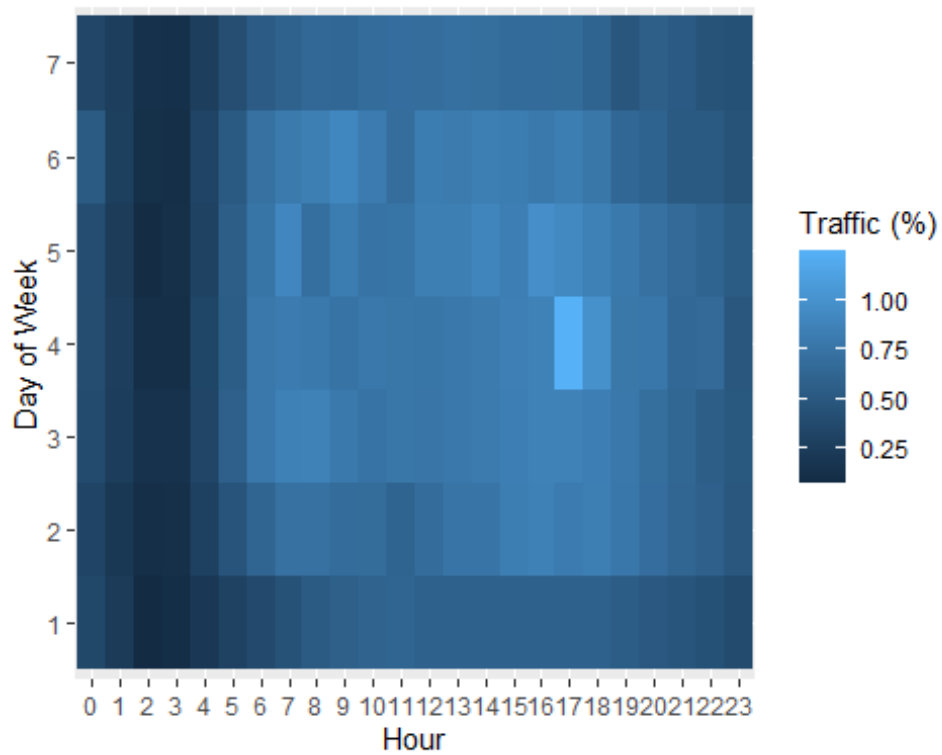
# get the table
dt.date <- as.data.frame(table(dt$Date)/nrow(dt)*100)
# rename
names(dt.date)[1] <- "Date"
# convert to date
dt.date$Date <- as.Date(strftime(as.character(dt.date$Date), format = "%Y-%m-%d", tz = ""))
# plot daily
plot(dt.date, type = "l", xlab = "", ylab = "Traffic Load (%)", col = "red",
main = "Daily Traffic Load in March, 2018")

```

Daily Traffic Load in March, 2018



```
#  
# get the table  
dt.hour_week <- as.data.frame(table(dt$HOUR, dt$DAY_OF_WEEK)/nrow(dt)*100)  
# rename  
names(dt.hour_week)[1:2] <- c("Hour", "Day_of_week")  
  
dow <- c('Sunday', 'Monday', 'Tuesday', 'Wednesday', 'Thursday', 'Friday', 'Saturday')  
  
mine.heatmap <- ggplot(data = dt.hour_week, mapping = aes(x = Hour, y = Day_of_week, fill = Freq)) +  
  geom_tile() +  
  labs(  
    x = "Hour",  
    y = "Day of Week",  
    fill = "Traffic (%)"  
  )  
mine.heatmap
```



The daily traffic load curve has the obvious weekly periodicity which may be also observed in the heatmap by hours and days of week. The most of the traffic hit on 17 o'clock Wednesday. Minimal loads are observed after midnight and on weekend.