In [1]:
```
import pandas as pd
import numpy as np
import statistics
from statistics import mean
import matplotlib.pyplot as plt
from matplotlib import dates as mpl_dates
```

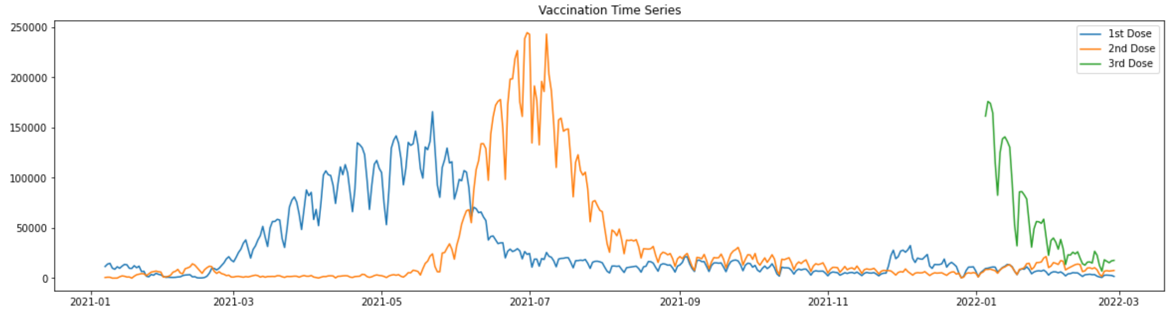
In [2]:
```
df=pd.read_excel('C:\\Users\\eric.park\\Downloads\\vaccine_doses.xlsx')
```

In [3]:
```
dft=df[['report_date','previous_day_at_least_one','previous_day_fully_vaccina
```

In [4]:
```
#Time Series
```

In [5]:
```
y_ax=dft['previous_day_at_least_one']
y_ax1=df['previous_day_fully_vaccinated']
y_ax2=df['previous_day_3doses']
x_ax=dft['report_date']

plt.figure(figsize=(20,5))
plt.plot(x_ax,y_ax,label='1st Dose')
plt.plot(x_ax,y_ax1,label='2nd Dose')
plt.plot(x_ax,y_ax2, label='3rd Dose')

plt.legend()
plt.title('Vaccination Time Series')
```

Out[5]:
```
Text(0.5, 1.0, 'Vaccination Time Series')
```



In [6]:
```
#ADF Test on each subset
```

In [7]:
```
#null hypothesis->data is not stationary
```

In [8]:
```
from statsmodels.tsa.stattools import adfuller
```

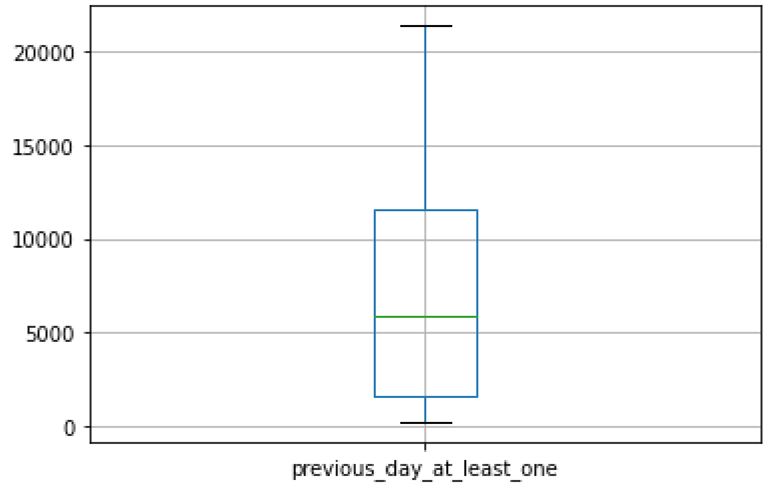
In [9]:
```
df1=dft[['report_date','previous_day_at_least_one']]
df1=df1.dropna()
#subset earliest 1st dose and 56 days from it
df1t=df1[(df1['report_date']>='2021-01-07')&(df1['report_date']<='2021-03-01'
```

In [10]:

```
df1t.boxplot()
```

Out[10]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x26cfe693160>
```

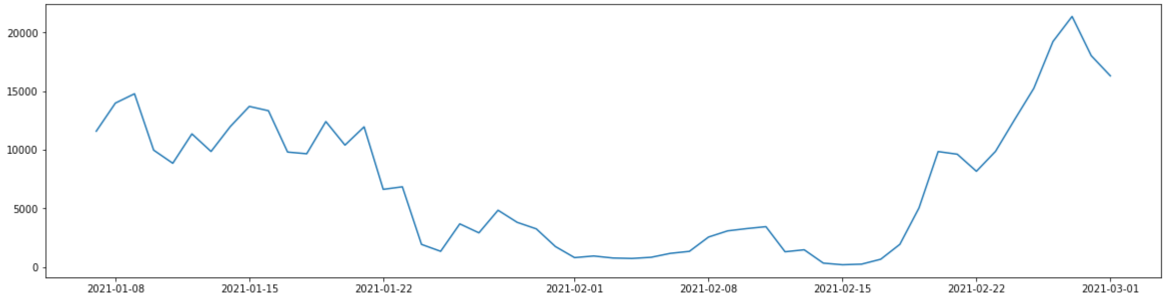


In [11]:

```
y_ax=df1t['previous_day_at_least_one']
x_ax=df1t['report_date']
plt.figure(figsize=(20,5))
plt.plot(x_ax,y_ax,label='1st Dose')
```

Out[11]:

```
[<matplotlib.lines.Line2D at 0x26cfe7066d0>]
```



In [12]:

```
series=df1t[['previous_day_at_least_one']]
result=adfuller(series)
print(f'Test Statistic: {result[0]}')
print(f'n_lags: {result[1]}')
print(f'p-value: {result[1]}')
for key, value in result[4].items():
    print('Critial Values:')
    print(f'   {key}, {value}')
```

```
Test Statistic: -2.1214787952108525
n_lags: 0.23596603211061395
p-value: 0.23596603211061395
Critial Values:
   1%, -3.5812576580093696
Critial Values:
   5%, -2.9267849124681518
Critial Values:
   10%, -2.6015409829867675
```

In [13]:

```
#does not reject null hypothesis because pvalue is greater than 0.05 & Test S
#This dataset is not stationary.
```

In [14]:

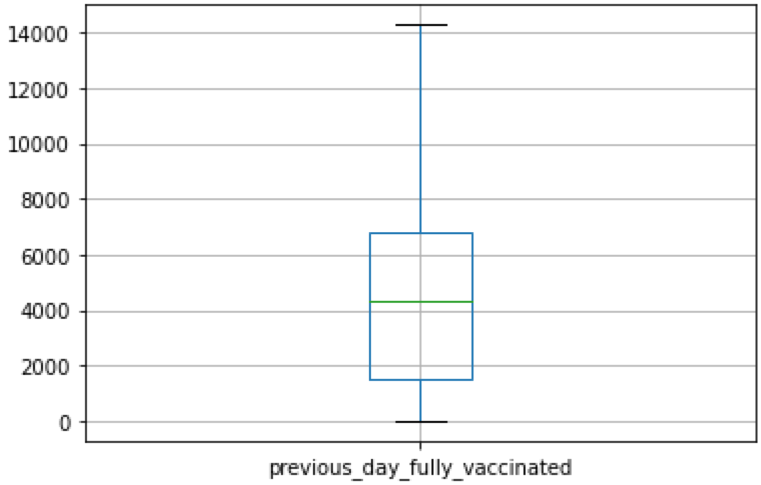
```
df2=dft[['report_date','previous_day_fully_vaccinated']]
df2=df2.dropna()
#subset earliest 2nd dose and 53 days from it
df2t=df2[(df2['report_date']>='2021-01-07')&(df1['report_date']<='2021-03-01'
```

In [15]:

```
df2t.boxplot()
```

Out[15]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x26cfe731250>
```

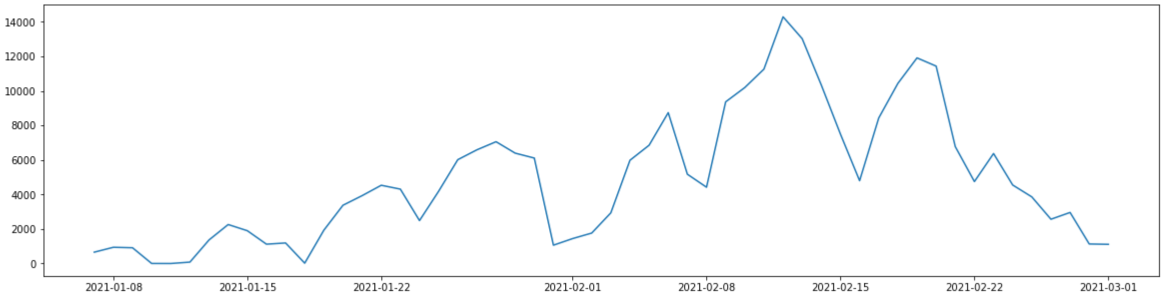


In [16]:

```
y_ax=df2t['previous_day_fully_vaccinated']
x_ax=df2t['report_date']
plt.figure(figsize=(20,5))
plt.plot(x_ax,y_ax,label='2nd Dose')
```

Out[16]:

```
[<matplotlib.lines.Line2D at 0x26cfc6f48b0>]
```



In [17]:

```
series1=df2t[['previous_day_fully_vaccinated']]
result1=adfuller(series1)
print(f'Test Statistic: {result1[0]}')
print(f'n_lags: {result1[1]}')
print(f'p-value: {result1[1]}')
for key, value in result1[4].items():
    print('Critial Values:')
    print(f'   {key}, {value}')
```

```
Test Statistic: -2.368125779639069
n_lags: 0.15093546335964309
p-value: 0.15093546335964309
Critial Values:
   1%, -3.562878534649522
Critial Values:
   5%, -2.918973284023669
Critial Values:
   10%, -2.597393446745562
```

In [18]:

```
#does not reject null hypothesis because pvalue is greater than 0.05 & Test S
#This dataset is not stationary.
```

In [19]:

```
df3=dft[['report_date','previous_day_3doses']]
df3=df3.dropna()
```

In [20]:

```
series2=df3[['previous_day_3doses']]
result=adfuller(series2)
print(f'Test Statistic: {result[0]}')
print(f'n_lags: {result[1]}')
print(f'p-value: {result[1]}')
for key, value in result[4].items():
    print('Critial Values:')
    print(f'   {key}, {value}')
```

```
Test Statistic: -4.196999303352296
n_lags: 0.0006664908409212250
p-value: 0.0006664908409212250
Critial Values:
   1%, -3.5812576580093696
Critial Values:
   5%, -2.9267849124681518
Critial Values:
   10%, -2.6015409829867675
```

In [21]:

```
#Rejects null hypothesis because pvalue is less than 0.05 & Test Statistics i
#This dataset is stationary.
```

In [22]:

```
#Seaonality decomposition
```

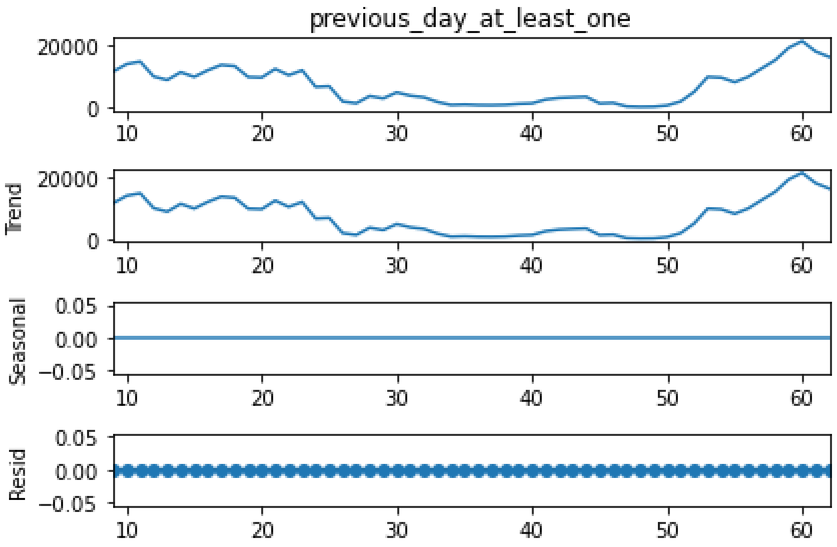
In [23]:

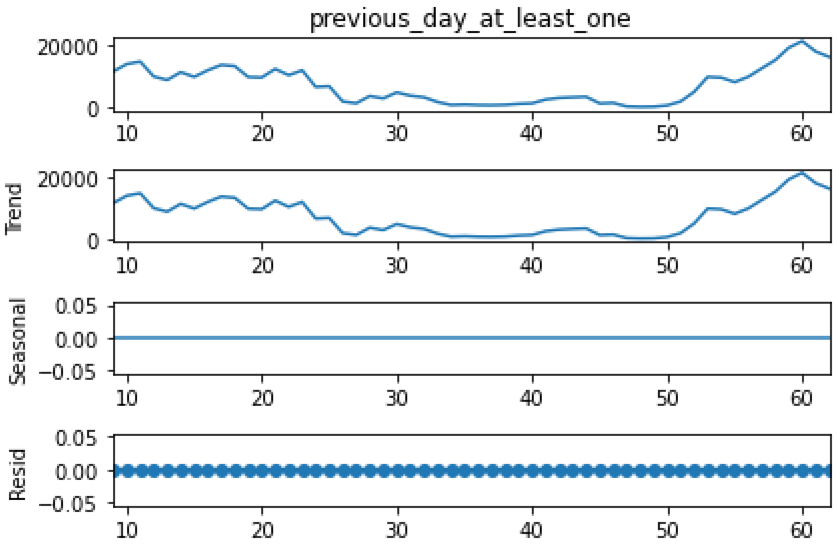
```
from statsmodels.tsa.seasonal import seasonal_decompose
```

In [24]:

```
result = seasonal_decompose(df1t['previous_day_at_least_one'], model="additiv

trend = result.trend
seasonal = result.seasonal
residual = result.resid

result.plot()
```

Out[24]:

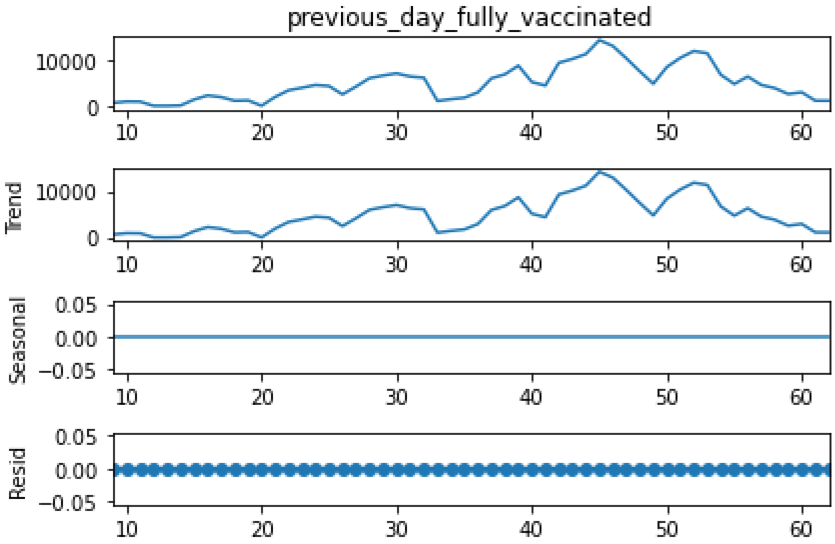


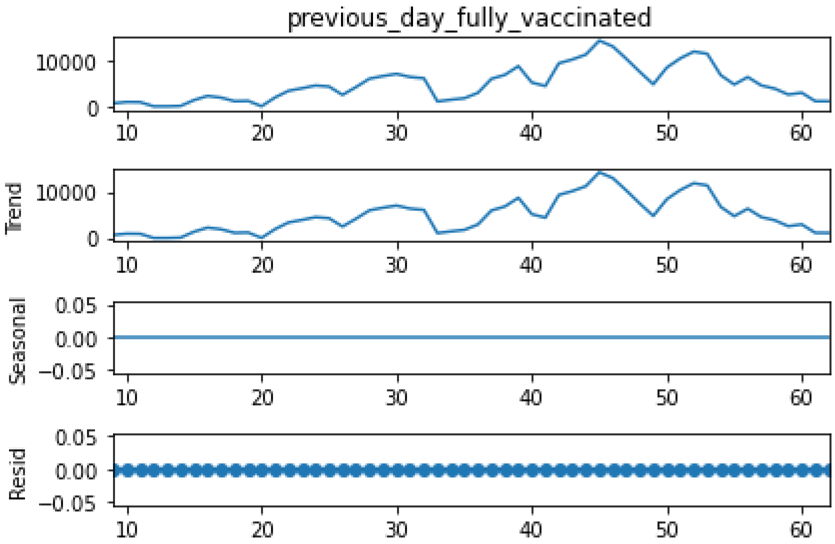


In [25]:

```
result1 = seasonal_decompose(df2t['previous_day_fully_vaccinated'], model="ac

trend = result1.trend
seasonal = result1.seasonal
residual = result1.resid

result1.plot()
```

Out[25]:

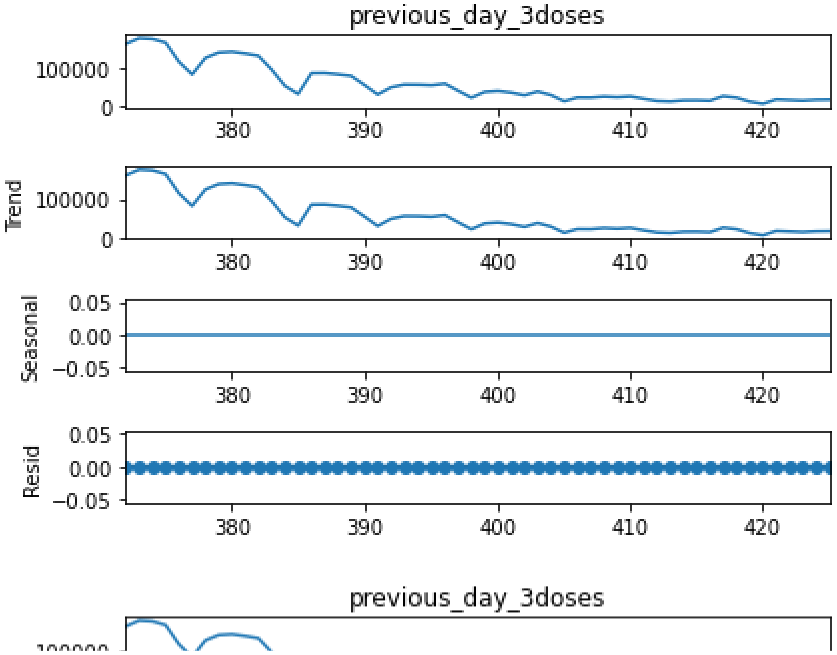




In [26]:

```
result2 = seasonal_decompose(df3['previous_day_3doses'], model="additive", pe

trend = result2.trend
seasonal = result2.seasonal
residual = result2.resid

result2.plot()
```

Out[26]:



In [27]:

```
#Logarithmic Transformation
```

In [28]:

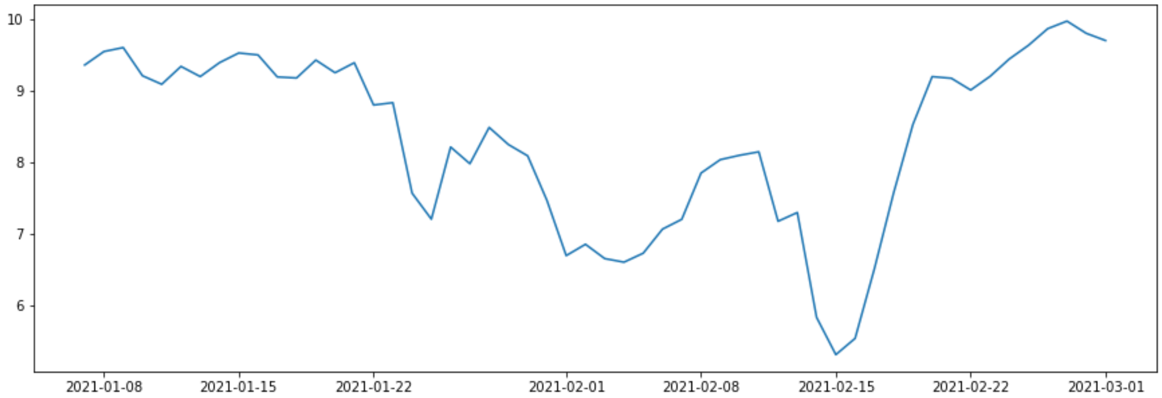
```
df1t_t=np.log(df1t['previous_day_at_least_one'])
df1_t=pd.DataFrame(data=df1t_t)
df1_t['previous_day_at_least_one_log']=df1_t['previous_day_at_least_one']
df1_t=df1_t[['previous_day_at_least_one_log']]
df_1_dose=pd.concat([df1_t,df1t],axis=1)
df_1_dose=df_1_dose[['report_date','previous_day_at_least_one_log']]
```

In [29]:

```
plt.figure(figsize=(15,5))
plt.plot(df_1_dose['report_date'],df_1_dose['previous_day_at_least_one_log'])
```

Out[29]:

```
[<matplotlib.lines.Line2D at 0x26cfeec9e50>]
```



In [30]:

```
np.seterr(divide='ignore')
df2t['previous_day_fully_vaccinated']=df2t['previous_day_fully_vaccinated'].r

df2t_t=np.log(df2t['previous_day_fully_vaccinated'])
df2_t=pd.DataFrame(data=df2t_t)
df2_t['previous_day_fully_vaccinated_log']=df2_t['previous_day_fully_vaccinat
df2_t=df2_t[['previous_day_fully_vaccinated_log']]
df_2_dose=pd.concat([df2_t,df2t],axis=1)
df_2_dose=df_2_dose[['report_date','previous_day_fully_vaccinated_log']]
df_2_dose['previous_day_fully_vaccinated_log'][df_2_dose['previous_day_fully_
```

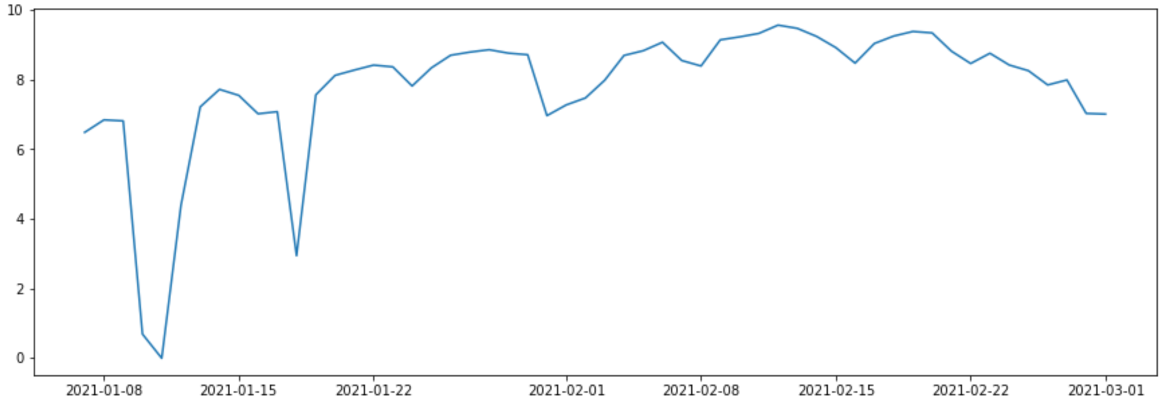
```
<ipython-input-30-98a15cc7eb4b>:2: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-doc
s/stable/user_guide/indexing.html#returning-a-view-versus-a-copy (https://p
andas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-vi
ew-versus-a-copy)
  df2t['previous_day_fully_vaccinated']=df2t['previous_day_fully_vaccinate
d'].replace(0,0.01)
```

In [31]:

```
plt.figure(figsize=(15,5))
plt.plot(df_2_dose['report_date'],df_2_dose['previous_day_fully_vaccinated_lo
```

Out[31]:

```
[<matplotlib.lines.Line2D at 0x26cfef5f610>]
```



In [32]:

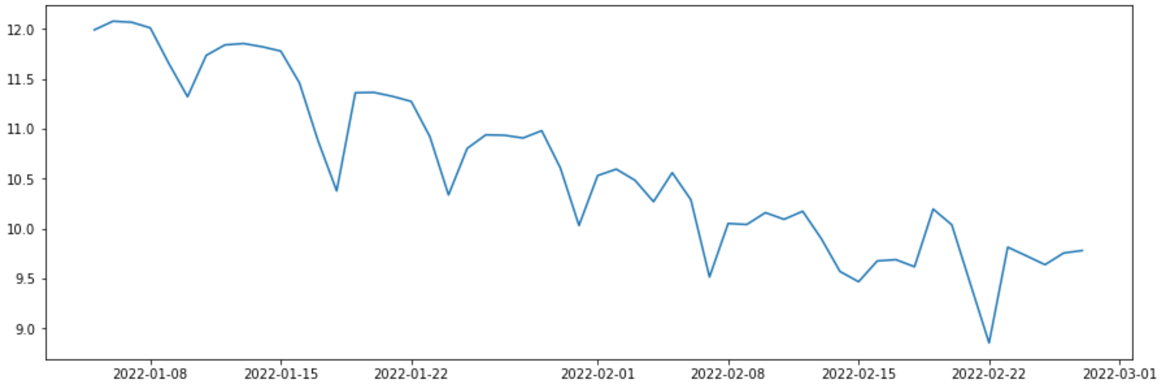
```
df3t_t=np.log(df3['previous_day_3doses'])
df3_t=pd.DataFrame(data=df3t_t)
df3_t['previous_day_3doses_log']=df3_t['previous_day_3doses']
df3_t=df3_t[['previous_day_3doses_log']]
df_3_dose=pd.concat([df3_t,df3],axis=1)
df_3_dose=df_3_dose[['report_date','previous_day_3doses_log']]
```

In [33]:

```
plt.figure(figsize=(15,5))
plt.plot(df_3_dose['report_date'],df_3_dose['previous_day_3doses_log'])
```

Out[33]:

```
[<matplotlib.lines.Line2D at 0x26cfef75df0>]
```



In [34]:

```
series5=df_1_dose[['previous_day_at_least_one_log']]
result5=adfuller(series5)
print(f'Test Statistic: {result5[0]}')
print(f'n_lags: {result5[1]}')
print(f'p-value: {result5[1]}')
for key, value in result5[4].items():
    print('Critial Values:')
    print(f'   {key}, {value}')
```

```
Test Statistic: -2.5169071885196086
n_lags: 0.11141462978447453
p-value: 0.11141462978447453
Critial Values:
   1%, -3.5656240522121956
Critial Values:
   5%, -2.920142229157715
Critial Values:
   10%, -2.598014675124952
```

In [35]:

```
#still Non Stationary. Most likely because the sample size is too small
```

In [36]:

```
series6=df_2_dose[['previous_day_fully_vaccinated_log']]
result6=adfuller(series6)
print(f'Test Statistic: {result6[0]}')
print(f'n_lags: {result6[1]}')
print(f'p-value: {result6[1]}')
for key, value in result6[4].items():
    print('Critial Values:')
    print(f'   {key}, {value}')
```

```
Test Statistic: -1.6116171554962435
n_lags: 0.47712674610728933
p-value: 0.47712674610728933
Critial Values:
   1%, -3.584828853223594
Critial Values:
   5%, -2.9282991495198907
Critial Values:
   10%, -2.6023438271604937
```

In [37]:

```
#still Non Stationary. Most likely because the sample size is too small
```

In [38]:

```
#Differencing
```

In [39]:

```
df1t['1st_dose_differencing']=df1t['previous_day_at_least_one']-df1t['previou
```

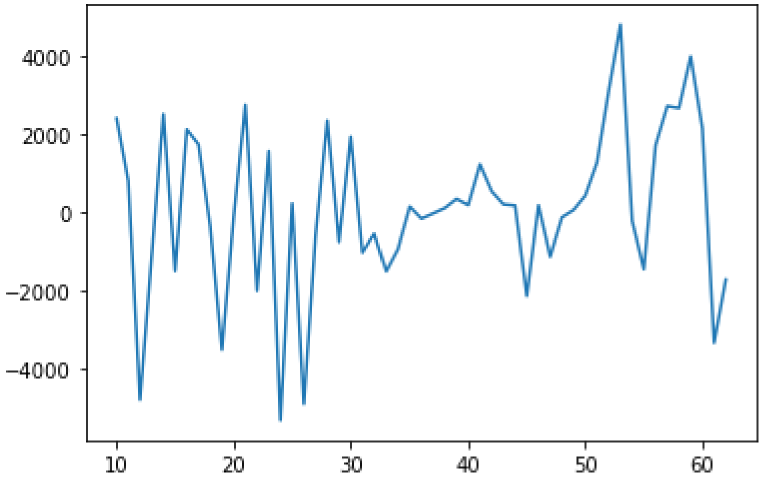
```
<ipython-input-39-c4ed2955dca7>:1: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-doc
s/stable/user_guide/indexing.html#returning-a-view-versus-a-copy (https://p
andas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-vi
ew-versus-a-copy)
  df1t['1st_dose_differencing']=df1t['previous_day_at_least_one']-df1t['pre
vious_day_at_least_one'].shift(1)
```

In [40]:

```
df1t['1st_dose_differencing'].plot()
```

Out[40]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x26cff54baf0>
```



In [41]:

```
series1=df1t[['1st_dose_differencing']]
result1=adfuller(series1.dropna())
print(f'Test Statistic: {result1[0]}')
print(f'n_lags: {result1[1]}')
print(f'p-value: {result1[1]}')
for key, value in result1[4].items():
    print('Critial Values:')
    print(f'   {key}, {value}')
```

```
Test Statistic: -6.414842214971217
n_lags: 1.852205812488052e-08
p-value: 1.852205812488052e-08
Critial Values:
   1%, -3.562878534649522
Critial Values:
   5%, -2.918973284023669
Critial Values:
   10%, -2.597393446745562
```

In [42]:

```
#P-Value is less than 0.05, it rejects the null hypthesis. We can can conclu
```

In [43]:

```
df2t['2nd_dose_differencing']=df2t['previous_day_fully_vaccinated']-df2t['pre
```

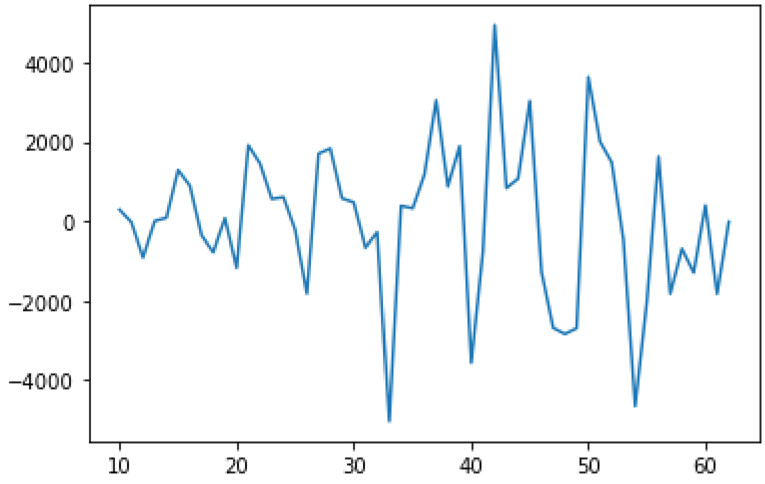
```
<ipython-input-43-550471bcad15>:1: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-doc
s/stable/user_guide/indexing.html#returning-a-view-versus-a-copy (https://p
andas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-vi
ew-versus-a-copy)
  df2t['2nd_dose_differencing']=df2t['previous_day_fully_vaccinated']-df2t
['previous_day_fully_vaccinated'].shift(1)
```

In [44]:

```
df2t['2nd_dose_differencing'].plot()
```

Out[44]:

```
<matplotlib.axes._subplots.AxesSubplot at 0x26cff2cd580>
```



In [45]:

```
series4=df2t[['2nd_dose_differencing']]
result4=adfuller(series4.dropna())
print(f'Test Statistic: {result4[0]}')
print(f'n_lags: {result4[1]}')
print(f'p-value: {result4[1]}')
for key, value in result4[4].items():
    print('Critial Values:')
    print(f'   {key}, {value}')
```

```
Test Statistic: -5.612074421073215
n_lags: 1.1971796068590797e-06
p-value: 1.1971796068590797e-06
Critial Values:
   1%, -3.5714715250448363
Critial Values:
   5%, -2.922629480573571
Critial Values:
   10%, -2.5993358475635153
```

In [46]:

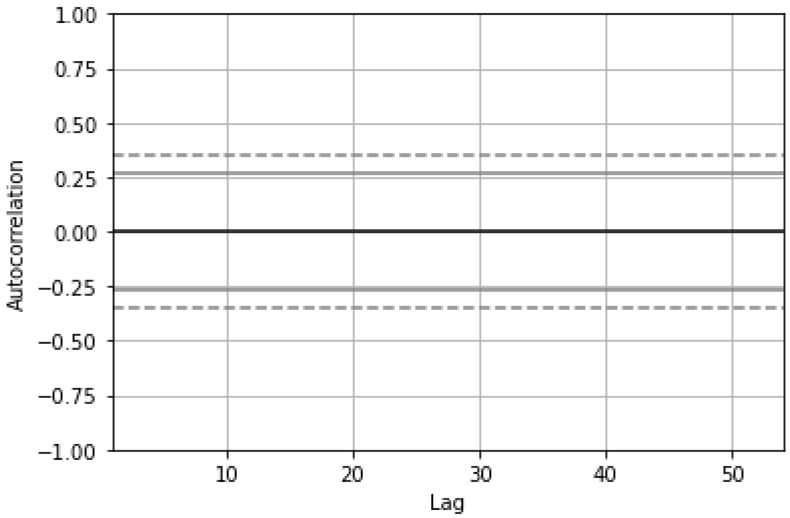
```
#P-Value is less than 0.05, it rejects the null hypthesis. We can can conclua
```

In [47]:

```
#Forecast - ARIMA
```

In [48]:

```
%%time
#autocorrecation for 1st Dose
from pandas.plotting import autocorrelation_plot
autocorrelation_plot(df1t['1st_dose_differencing'])
plt.show()
```

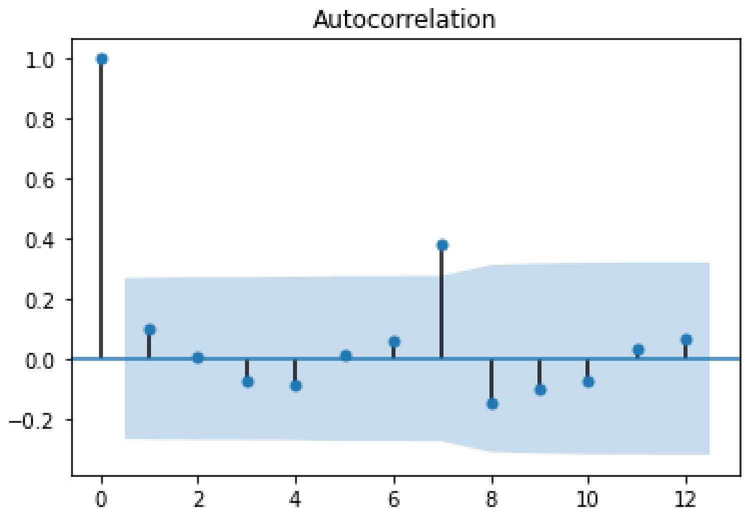


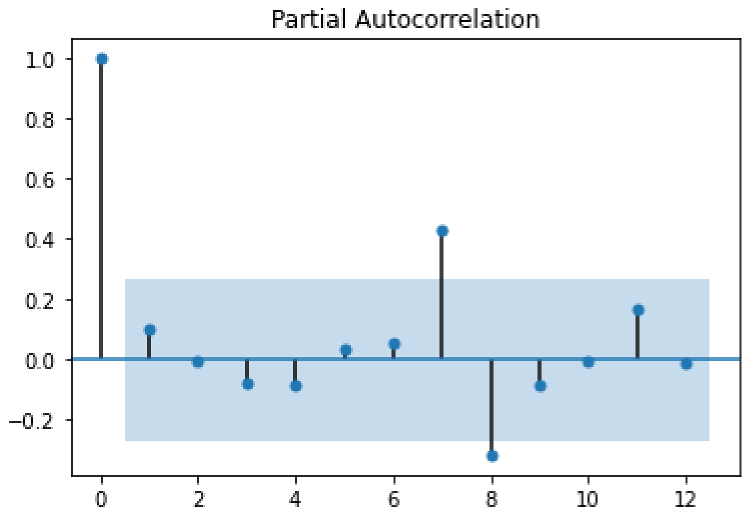
```
Wall time: 1.01 s
```

In [49]:

```
%%time
from statsmodels.graphics.tsaplots import plot_acf,plot_pacf
import statsmodels.api as sm
fig = plt.figure(figsize=(12,8))

fig = sm.graphics.tsa.plot_acf(df1t['1st_dose_differencing'].dropna(),lags=12
fig = sm.graphics.tsa.plot_pacf(df1t['1st_dose_differencing'].dropna(),lags=1
```

```
Wall time: 1.34 s

<Figure size 864x576 with 0 Axes>
```





In [50]:

```
from statsmodels.tsa.arima_model import ARIMA
```

In [51]:

```
%%time
model1=ARIMA(df1t['1st_dose_differencing'].dropna(),order=(6,0,3))
```

```
Wall time: 55 ms

C:\ProgramData\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.p
y:213: ValueWarning: An unsupported index was provided and will be ignored
when e.g. forecasting.
  warnings.warn('An unsupported index was provided and will be'
```

In [52]:

```
%%time
model_fit1=model1.fit()
```

```
Wall time: 12 s

C:\ProgramData\Anaconda3\lib\site-packages\statsmodels\base\model.py:547: H
essianInversionWarning: Inverting hessian failed, no bse or cov_params avai
lable
  warn('Inverting hessian failed, no bse or cov_params '
```

In [53]:

```
%%time
model_fit1.summary()
```

```
Wall time: 1.01 s
```

Out[53]:

ARMA Model Results

Dep. Variable:	1st_dose_differencing	**No. Observations:**	53
Model:	ARMA(6, 3)	**Log Likelihood**	-476.109
Method:	css-mle	**S.D. of innovations**	1815.845
Date:	Mon, 28 Mar 2022	**AIC**	974.218
Time:	23:31:31	**BIC**	995.891
Sample:	0	**HQIC**	982.553

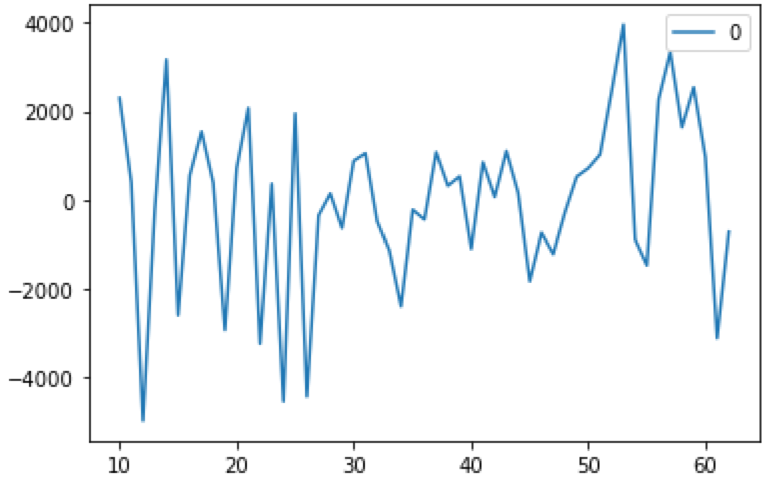
	coef	**std err**	**z**	**P>|z|**	**[0.025**	**0.975]**
const	95.4196	294.793	0.324	0.746	-482.365	673.204
ar.L1.1st_dose_differencing	0.0811	0.149	0.545	0.586	-0.211	0.373
ar.L2.1st_dose_differencing	0.0476	0.147	0.324	0.746	-0.240	0.335
ar.L3.1st_dose_differencing	-0.8432	0.148	-5.704	0.000	-1.133	-0.553
ar.L4.1st_dose_differencing	-0.1264	0.151	-0.835	0.403	-0.423	0.170
ar.L5.1st_dose_differencing	0.1232	0.152	0.812	0.417	-0.174	0.420
ar.L6.1st_dose_differencing	-0.0027	0.150	-0.018	0.985	-0.297	0.292
ma.L1.1st_dose_differencing	0.0188	0.131	0.143	0.886	-0.238	0.276
ma.L2.1st_dose_differencing	0.0188	0.131	0.143	0.886	-0.238	0.275
ma.L3.1st_dose_differencing	1.0000	0.164	6.088	0.000	0.678	1.322

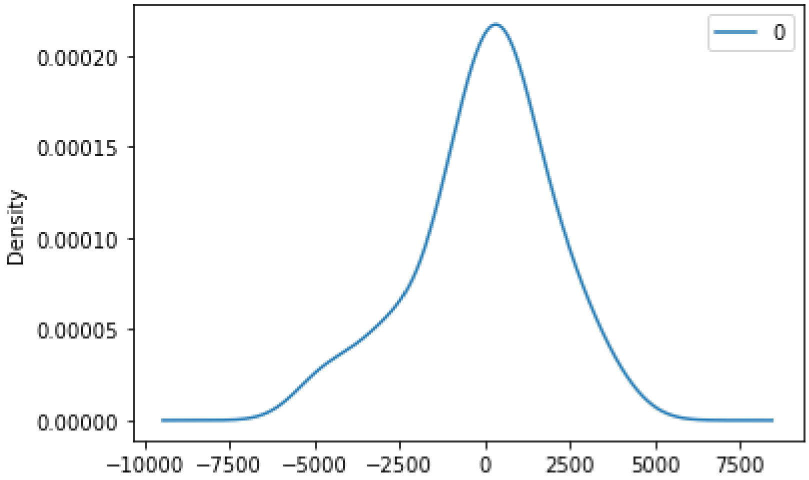
Roots

	Real	**Imaginary**	**Modulus**	**Frequency**
AR.1	0.5354	-0.8534j	1.0074	-0.1608
AR.2	0.5354	+0.8534j	1.0074	0.1608
AR.3	-1.3029	-0.0000j	1.3029	-0.5000
AR.4	-1.8907	-0.0000j	1.8907	-0.5000
AR.5	3.3379	-0.0000j	3.3379	-0.0000
AR.6	43.7504	-0.0000j	43.7504	-0.0000
MA.1	-1.0000	-0.0000j	1.0000	-0.5000
MA.2	0.4906	-0.8714j	1.0000	-0.1684
MA.3	0.4906	+0.8714j	1.0000	0.1684

In [54]:

```
%%time
residuals = pd.DataFrame(model_fit1.resid)
residuals.plot()
plt.show()
# density plot of residuals
residuals.plot(kind='kde')
plt.show()
# summary stats of residuals
print(residuals.describe())
```





```
                 0
count    53.000000
mean    -17.970466
std    1969.401515
min   -4985.006700
25%    -894.567316
50%     316.206773
75%    1053.299822
max    3964.514126
Wall time: 1.16 s
```

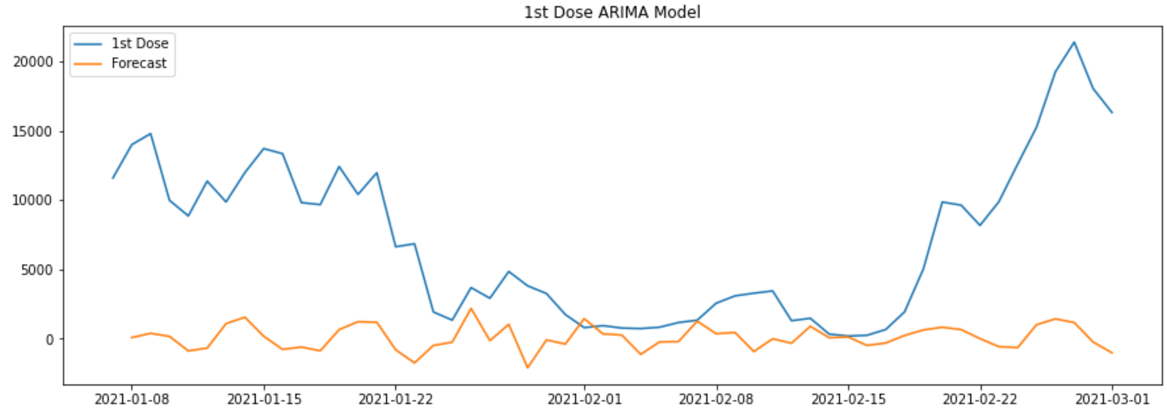
In [55]:

```
%%time
df1t['forecast']=model_fit1.predict(dynamic=False)

y_ax1=df1t['forecast']
y_ax2=df1t['previous_day_at_least_one']
x_ax=df1t['report_date']

plt.figure(figsize=(15,5))
plt.plot(x_ax,y_ax2,label='1st Dose')
plt.plot(x_ax,y_ax1,label='Forecast')


plt.legend()
plt.title('1st Dose ARIMA Model')
```

```
Wall time: 38 ms

<timed exec>:1: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-doc
s/stable/user_guide/indexing.html#returning-a-view-versus-a-copy (https://p
andas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-vi
ew-versus-a-copy)
```

Out[55]:

```
Text(0.5, 1.0, '1st Dose ARIMA Model')
```



In [56]:

```
df1t.head()
```

Out[56]:

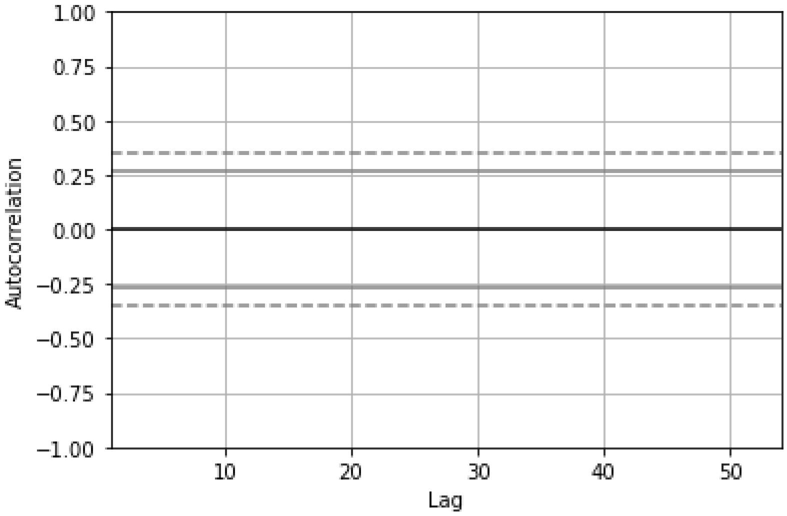
	report_date	previous_day_at_least_one	1st_dose_differencing	forecast
9	2021-01-07	11594.0	NaN	NaN
10	2021-01-08	13992.0	2398.0	95.419627
11	2021-01-09	14787.0	795.0	400.154574
12	2021-01-10	9981.0	-4806.0	179.006700
13	2021-01-11	8859.0	-1122.0	-865.853639

In [57]:

```
#autocorrecation for 2nd Dose
```

In [58]:

```
%%time
autocorrelation_plot(df2t['2nd_dose_differencing'])
plt.show()
```



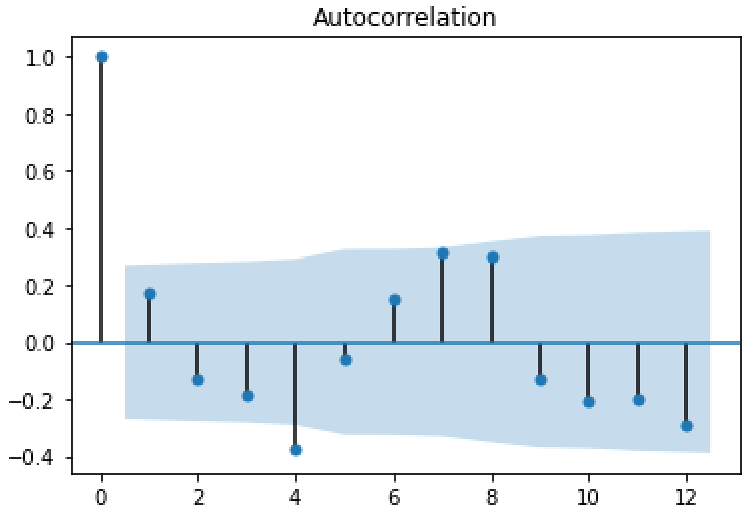
```
Wall time: 422 ms
```

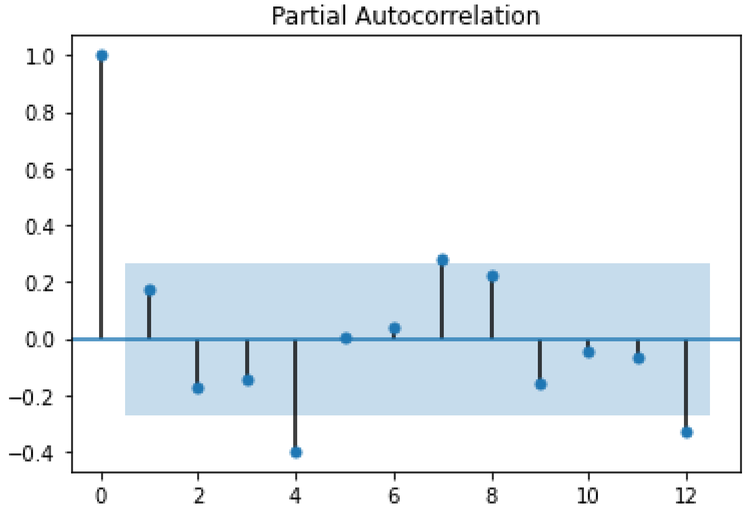
In [59]:

```
%%time
from statsmodels.graphics.tsaplots import plot_acf,plot_pacf
import statsmodels.api as sm
fig = plt.figure(figsize=(12,8))

fig = sm.graphics.tsa.plot_acf(df2t['2nd_dose_differencing'].dropna(),lags=12
fig = sm.graphics.tsa.plot_pacf(df2t['2nd_dose_differencing'].dropna(),lags=1
```

```
Wall time: 157 ms
```

```
<Figure size 864x576 with 0 Axes>
```





In [60]:

```
%%time
model2=ARIMA(df2t['2nd_dose_differencing'].dropna(),order=(6,0,3))
```

```
Wall time: 3 ms

C:\ProgramData\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.p
y:213: ValueWarning: An unsupported index was provided and will be ignored
when e.g. forecasting.
  warnings.warn('An unsupported index was provided and will be'
```

In [61]:

```
%%time
model_fit2=model2.fit()
```

```
C:\ProgramData\Anaconda3\lib\site-packages\statsmodels\tsa\tsatools.py:689:
RuntimeWarning: overflow encountered in exp
  newparams = ((1-np.exp(-params))/(1+np.exp(-params))).copy()
C:\ProgramData\Anaconda3\lib\site-packages\statsmodels\tsa\tsatools.py:689:
RuntimeWarning: invalid value encountered in true_divide
  newparams = ((1-np.exp(-params))/(1+np.exp(-params))).copy()
C:\ProgramData\Anaconda3\lib\site-packages\statsmodels\tsa\tsatools.py:690:
RuntimeWarning: overflow encountered in exp
  tmp = ((1-np.exp(-params))/(1+np.exp(-params))).copy()
C:\ProgramData\Anaconda3\lib\site-packages\statsmodels\tsa\tsatools.py:690:
RuntimeWarning: invalid value encountered in true_divide
  tmp = ((1-np.exp(-params))/(1+np.exp(-params))).copy()

Wall time: 3.4 s

C:\ProgramData\Anaconda3\lib\site-packages\statsmodels\base\model.py:547: H
essianInversionWarning: Inverting hessian failed, no bse or cov_params avai
lable
  warn('Inverting hessian failed, no bse or cov_params '
C:\ProgramData\Anaconda3\lib\site-packages\statsmodels\base\model.py:567: C
onvergenceWarning: Maximum Likelihood optimization failed to converge. Chec
k mle_retvals
  warn("Maximum Likelihood optimization failed to converge. "
```

In [62]:

```
%%time
model_fit2.summary()
```

```
Wall time: 728 ms

C:\ProgramData\Anaconda3\lib\site-packages\statsmodels\tsa\arima_model.py:1
490: RuntimeWarning: invalid value encountered in sqrt
  return np.sqrt(np.diag(-inv(hess)))
```

Out[62]:

ARMA Model Results

Dep. Variable:	2nd_dose_differencing	**No. Observations:**	53
Model:	ARMA(6, 3)	**Log Likelihood**	-477.530
Method:	css-mle	**S.D. of innovations**	nan
Date:	Mon, 28 Mar 2022	**AIC**	977.060
Time:	23:31:39	**BIC**	998.733
Sample:	0	**HQIC**	985.394

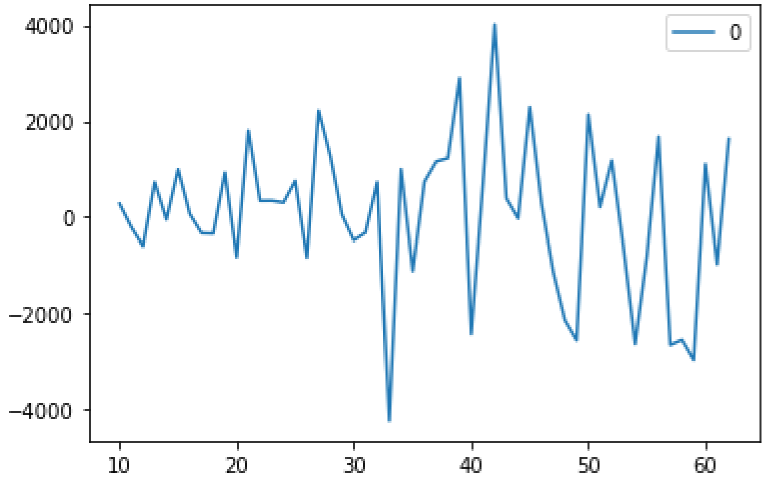
	coef	std err	z	P>|z|	[0.025	0.975]
const	8.5813	nan	nan	nan	nan	nan
ar.L1.2nd_dose_differencing	0.7870	2.52e-05	3.12e+04	0.000	0.787	0.787
ar.L2.2nd_dose_differencing	-0.6070	2e-05	-3.03e+04	0.000	-0.607	-0.607
ar.L3.2nd_dose_differencing	-0.1715	nan	nan	nan	nan	nan
ar.L4.2nd_dose_differencing	-0.3638	nan	nan	nan	nan	nan
ar.L5.2nd_dose_differencing	0.1782	nan	nan	nan	nan	nan
ar.L6.2nd_dose_differencing	-0.1033	nan	nan	nan	nan	nan
ma.L1.2nd_dose_differencing	-0.7903	0.123	-6.406	0.000	-1.032	-0.549
ma.L2.2nd_dose_differencing	0.4844	0.154	3.140	0.002	0.182	0.787
ma.L3.2nd_dose_differencing	0.4245	0.124	3.411	0.001	0.181	0.668

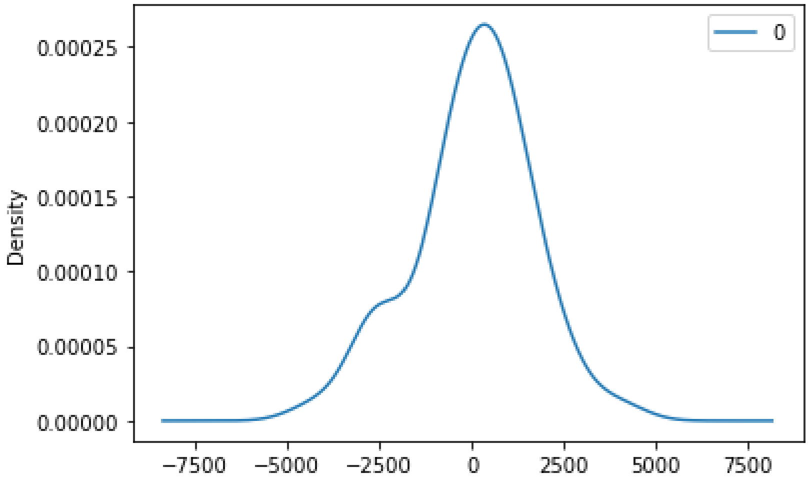
Roots

	Real	Imaginary	Modulus	Frequency
AR.1	0.6291	-0.7774j	1.0000	-0.1417
AR.2	0.6291	+0.7774j	1.0000	0.1417
AR.3	-0.9936	-1.0166j	1.4216	-0.3732
AR.4	-0.9936	+1.0166j	1.4216	0.3732
AR.5	1.2274	-1.8126j	2.1891	-0.1553
AR.6	1.2274	+1.8126j	2.1891	0.1553
MA.1	0.6074	-0.7944j	1.0000	-0.1461
MA.2	0.6074	+0.7944j	1.0000	0.1461
MA.3	-2.3560	-0.0000j	2.3560	-0.5000

In [63]:

```
%%time
residuals = pd.DataFrame(model_fit2.resid)
residuals.plot()
plt.show()
# density plot of residuals
residuals.plot(kind='kde')
plt.show()
# summary stats of residuals
print(residuals.describe())
```





```
                 0
count    53.000000
mean     47.486541
std    1594.890941
min   -4240.439385
25%    -809.684795
50%     274.418741
75%     995.774248
max    4017.240343
Wall time: 1.04 s
```

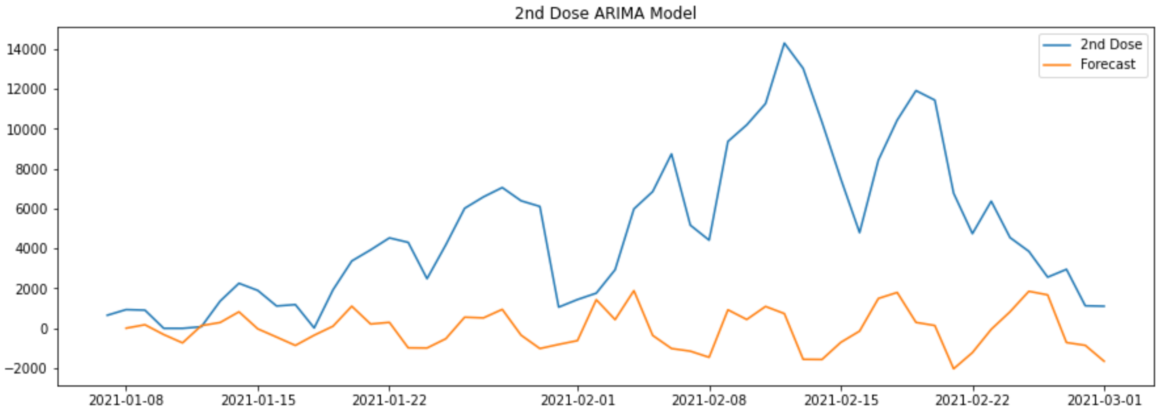
In [64]:

```
%%time
df2t['forecast']=model_fit2.predict(dynamic=False)

y_ax=df2t['previous_day_fully_vaccinated']
y_ax1=df2t['forecast']
x_ax=df2t['report_date']

plt.figure(figsize=(15,5))
plt.plot(x_ax,y_ax,label='2nd Dose')
plt.plot(x_ax,y_ax1,label='Forecast')


plt.legend()
plt.title('2nd Dose ARIMA Model')
```

```
Wall time: 70 ms

<timed exec>:1: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy (https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a-view-versus-a-copy)
```

Out[64]:

```
Text(0.5, 1.0, '2nd Dose ARIMA Model')
```

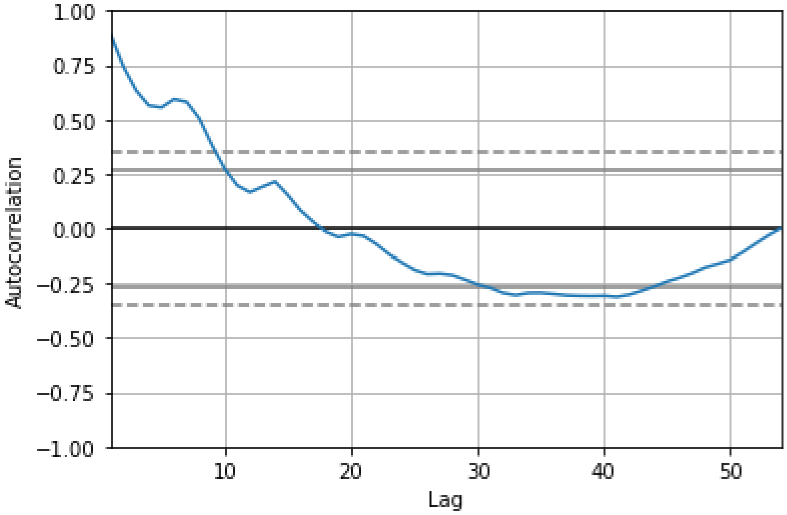


In [65]:

```
#autocorrecation for 3rd Dose
```

In [66]:

```
%%time
from pandas.plotting import autocorrelation_plot
autocorrelation_plot(df3['previous_day_3doses'])
plt.show()
```



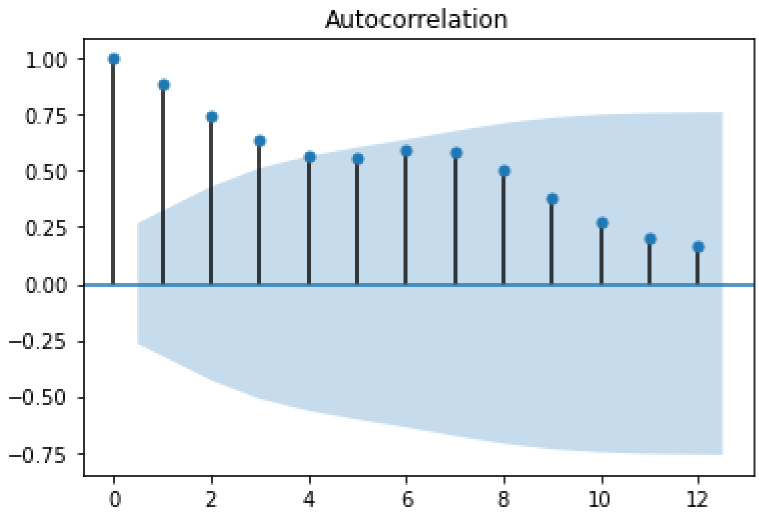
```
Wall time: 271 ms
```

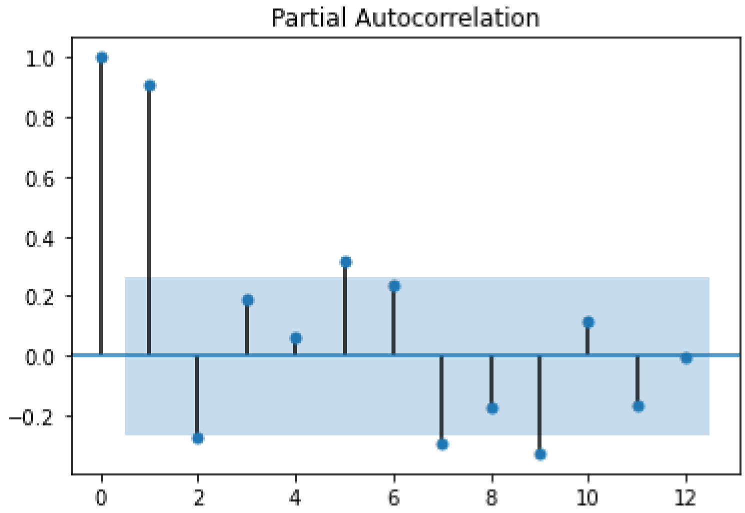
In [67]:

```
%%time
from statsmodels.graphics.tsaplots import plot_acf,plot_pacf
import statsmodels.api as sm
fig = plt.figure(figsize=(12,8))

fig = sm.graphics.tsa.plot_acf(df3['previous_day_3doses'].dropna(),lags=12)
fig = sm.graphics.tsa.plot_pacf(df3['previous_day_3doses'].dropna(),lags=12)
```

```
Wall time: 417 ms
```

```
<Figure size 864x576 with 0 Axes>
```





In [68]:

```
from statsmodels.tsa.arima_model import ARIMA
```

In [69]:

```
%%time
model=ARIMA(df3['previous_day_3doses'],order=(6,0,4))
```

```
Wall time: 996 µs
```

```
C:\ProgramData\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.p
y:213: ValueWarning: An unsupported index was provided and will be ignored
when e.g. forecasting.
  warnings.warn('An unsupported index was provided and will be'
```

In [70]:

```
%%time
model_fit=model.fit()
```

```
Wall time: 19.2 s

C:\ProgramData\Anaconda3\lib\site-packages\statsmodels\base\model.py:547: H
essianInversionWarning: Inverting hessian failed, no bse or cov_params avai
lable
  warn('Inverting hessian failed, no bse or cov_params '
```

In [71]:

```
%%time
model_fit.summary()
```

```
Wall time: 976 ms

C:\ProgramData\Anaconda3\lib\site-packages\statsmodels\tsa\arima_model.py:1
490: RuntimeWarning: invalid value encountered in sqrt
  return np.sqrt(np.diag(-inv(hess)))
```

Out[71]:

ARMA Model Results

Dep. Variable:	previous_day_3doses	**No. Observations:**	54
Model:	ARMA(6, 4)	**Log Likelihood**	-586.468
Method:	css-mle	**S.D. of innovations**	10947.505
Date:	Mon, 28 Mar 2022	**AIC**	1196.935
Time:	23:32:03	**BIC**	1220.803
Sample:	0	**HQIC**	1206.140

	coef	**std err**	**z**	**P>|z|**	**[0.025**	**0.975]**
const	5.705e+04	5.32e+04	1.073	0.283	-4.72e+04	1.61e+05
ar.L1.previous_day_3doses	2.2777	0.166	13.730	0.000	1.953	2.603
ar.L2.previous_day_3doses	-3.0119	0.320	-9.413	0.000	-3.639	-2.385
ar.L3.previous_day_3doses	3.1959	0.391	8.183	0.000	2.430	3.961
ar.L4.previous_day_3doses	-2.7326	0.379	-7.214	0.000	-3.475	-1.990
ar.L5.previous_day_3doses	1.6377	0.316	5.182	0.000	1.018	2.257
ar.L6.previous_day_3doses	-0.3784	0.176	-2.152	0.031	-0.723	-0.034
ma.L1.previous_day_3doses	-1.3551	0.140	-9.650	0.000	-1.630	-1.080
ma.L2.previous_day_3doses	1.4637	0.147	9.987	0.000	1.176	1.751
ma.L3.previous_day_3doses	-1.3551	nan	nan	nan	nan	nan
ma.L4.previous_day_3doses	1.0000	nan	nan	nan	nan	nan

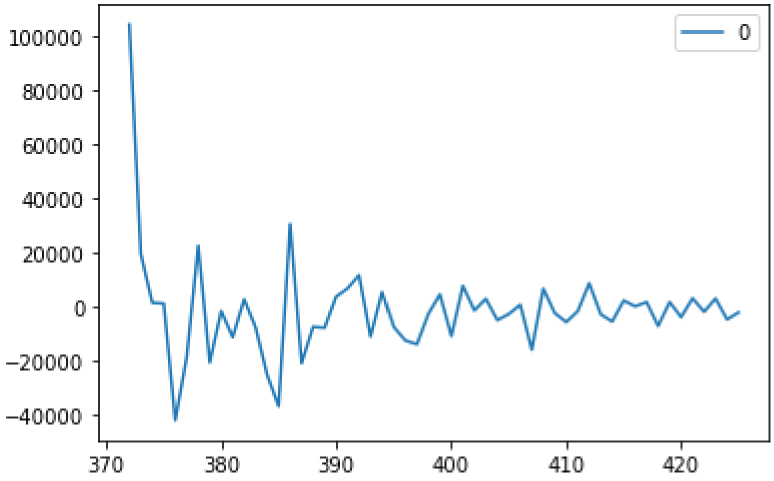
Roots

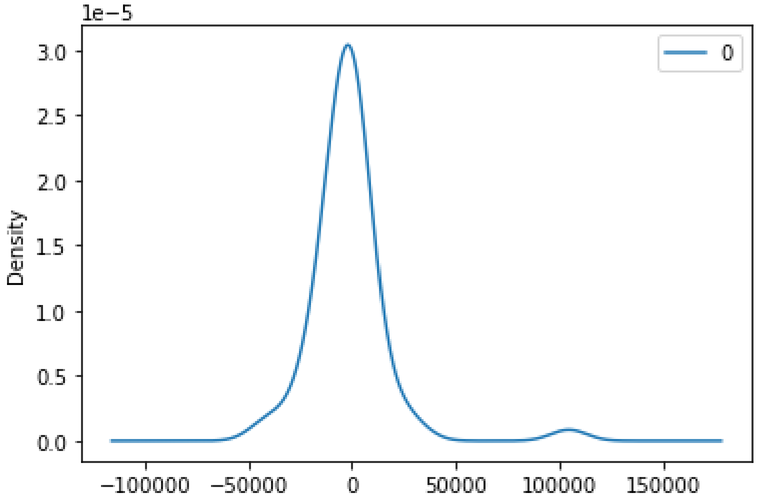
	Real	**Imaginary**	**Modulus**	**Frequency**
AR.1	-0.2065	-0.9832j	1.0047	-0.2829
AR.2	-0.2065	+0.9832j	1.0047	0.2829
AR.3	0.7085	-0.7848j	1.0573	-0.1331
AR.4	0.7085	+0.7848j	1.0573	0.1331
AR.5	1.0138	-0.0000j	1.0138	-0.0000
AR.6	2.3096	-0.0000j	2.3096	-0.0000
MA.1	-0.1601	-0.9871j	1.0000	-0.2756
MA.2	-0.1601	+0.9871j	1.0000	0.2756

MA.3	0.8376	-0.5462j	1.0000	-0.0920
MA.4	0.8376	+0.5462j	1.0000	0.0920

In [72]:

```
%%time
residuals = pd.DataFrame(model_fit.resid)
residuals.plot()
plt.show()
# density plot of residuals
residuals.plot(kind='kde')
plt.show()
# summary stats of residuals
print(residuals.describe())
```





```
                   0
count      54.000000
mean    -1481.283324
std     19236.270070
min    -42418.240205
25%     -7925.983560
50%     -2218.467700
75%      2811.463253
max    104434.294887
Wall time: 1.21 s
```

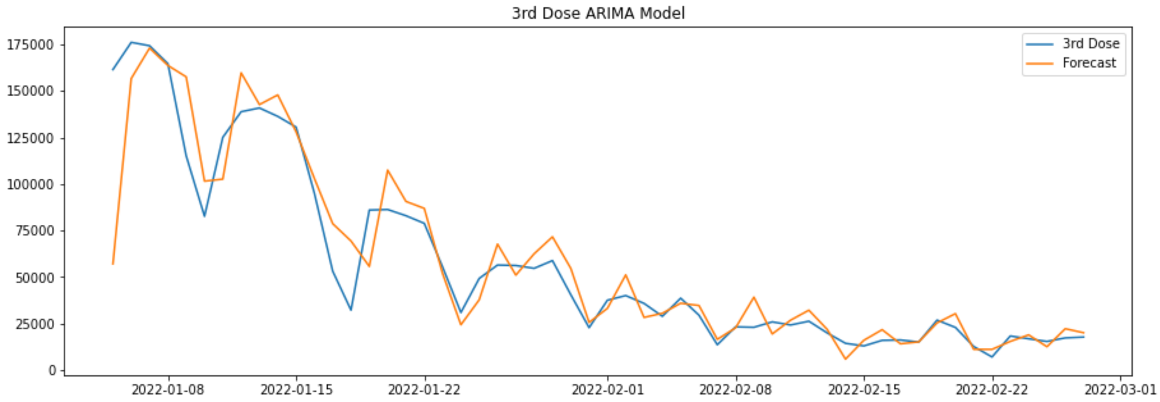
In [73]:

```
%%time

df3['forecast']=model_fit.predict(dynamic=False)

y_ax=df3['previous_day_3doses']
y_ax1=df3['forecast']
x_ax=df3['report_date']

plt.figure(figsize=(15,5))
plt.plot(x_ax,y_ax,label='3rd Dose')
plt.plot(x_ax,y_ax1,label='Forecast')


plt.legend()
plt.title('3rd Dose ARIMA Model')
```

```
Wall time: 66 ms
```

Out[73]:

```
Text(0.5, 1.0, '3rd Dose ARIMA Model')
```

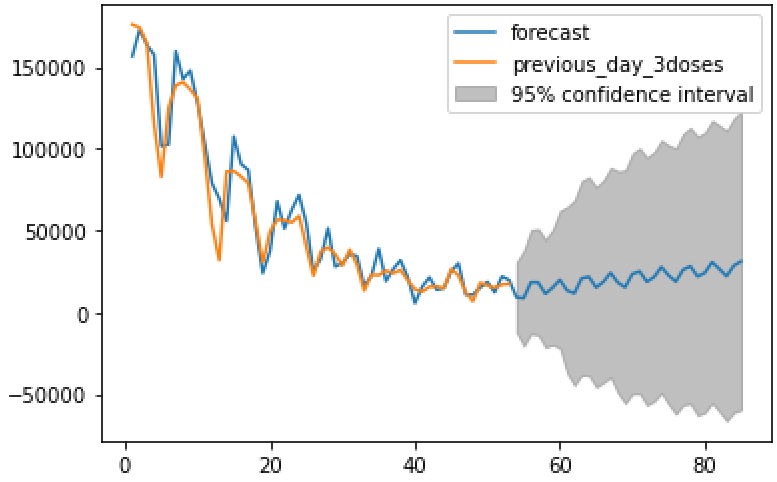


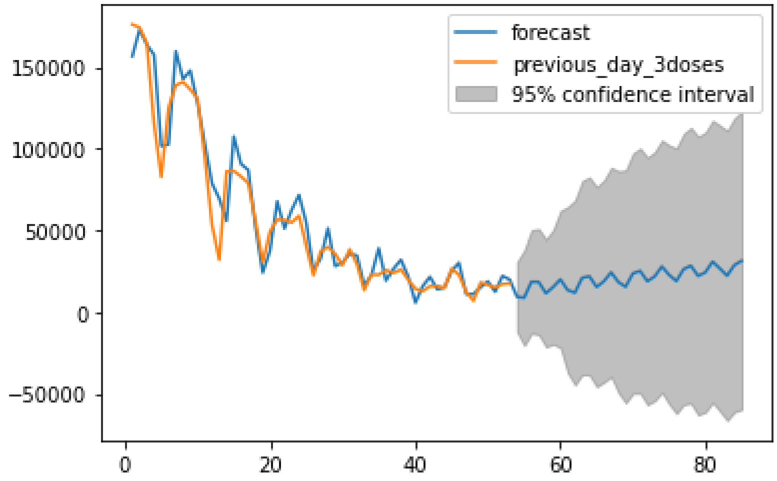
In [74]:

```
%%time
model_fit.plot_predict(start=1,end=85, alpha=0.05)
```

```
C:\ProgramData\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.p
y:580: ValueWarning: No supported index is available. Prediction results wi
ll be given with an integer index beginning at `start`.
  warnings.warn('No supported index is available.'
C:\ProgramData\Anaconda3\lib\site-packages\statsmodels\tsa\base\tsa_model.p
y:580: ValueWarning: No supported index is available. Prediction results wi
ll be given with an integer index beginning at `start`.
  warnings.warn('No supported index is available.'

Wall time: 127 ms
```

Out[74]:





In [140]:

```
from sklearn import metrics
print("MAE:"+ str(metrics.mean_absolute_error(y_test,y_pred)))
print("MSE:"+ str(metrics.mean_squared_error(y_test,y_pred)))
print("RMSE:"+str(np.sqrt(metrics.mean_squared_error(y_test,y_pred))))
```

```
MAE:8268.740533668644
MSE:156854677.14960158
RMSE:12524.1637305491
```

In [75]:

```
#regression for 1st dose
```

In [76]:

```
from sklearn.linear_model import LinearRegression
from sklearn.model_selection import train_test_split
```

In [77]:

```
%%time

x=df1t['report_date']
y=df1t['previous_day_at_least_one']

x_train, x_test, y_train, y_test = train_test_split(x, y, test_size=0.3)
```

```
Wall time: 2 ms
```

In [78]:

```
%%time

#create dataframe from trained data
report_date=x_train
f_vax=y_train
zipped = list(zip(report_date,f_vax))

temp_df = pd.DataFrame(zipped, columns=['Report_Date', 'Vaccine'])
sorted_df = temp_df.sort_values(by='Report_Date')
```

```
Wall time: 3 ms
```

In [79]:

```
%%time
#add ordinal value for date
l=[]
for i in range(len(sorted_df['Report_Date'])):
    i+=1
    l.append(i)
sorted_df['Order']=l
```

```
Wall time: 2 ms
```

In [80]:

```
%%time
model=LinearRegression()
```

```
Wall time: 0 ns
```

In [81]:

```
%%time

xx=sorted_df['Order']
yy=sorted_df['Vaccine']

model.fit(xx.values.reshape(-1,1),yy)
a=model.coef_
print("slope:"+ str(a))
b=model.intercept_
print("intercept:"+str(b))
print("model score:"+str(model.score(xx.values.reshape(-1,1),yy)))
```

```
slope:[-101.85727833]
intercept:9584.207207207208
model score:0.03366457195865458
Wall time: 5 ms
```

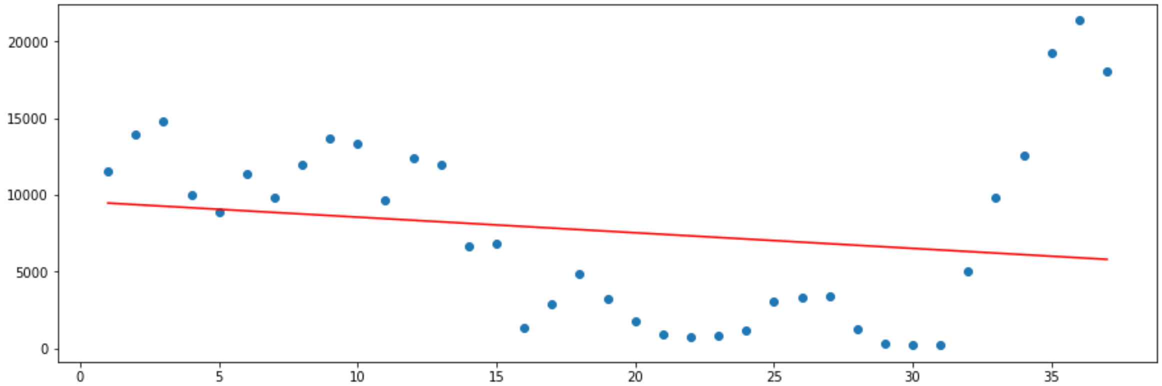
In [82]:

```
%%time

xx=sorted_df['Order']
yy=sorted_df['Vaccine']
plt.figure(figsize=(15,5))
plt.scatter(xx,yy)
a, b = np.polyfit(xx, yy, 1)
plt.plot(xx, a*xx+b, color='red')
```

```
Wall time: 41 ms
```

Out[82]:

```
[<matplotlib.lines.Line2D at 0x26c8420d820>]
```



In [83]:

```
%%time

#sorted test dataframe
report_date1=x_test
f_vax1=y_test
zipped = list(zip(report_date1,f_vax1))

temp_df1 = pd.DataFrame(zipped, columns=['Report_Date', 'Vaccine'])
sorted_df1 = temp_df.sort_values(by='Report_Date')
```

```
Wall time: 6 ms
```

In [84]:

```
%%time
#add ordinal value for date
l1=[]
for i in range(len(sorted_df1['Report_Date'])):
    i+=1
    l1.append(i)
sorted_df1['Order']=l1
```

```
Wall time: 2 ms
```

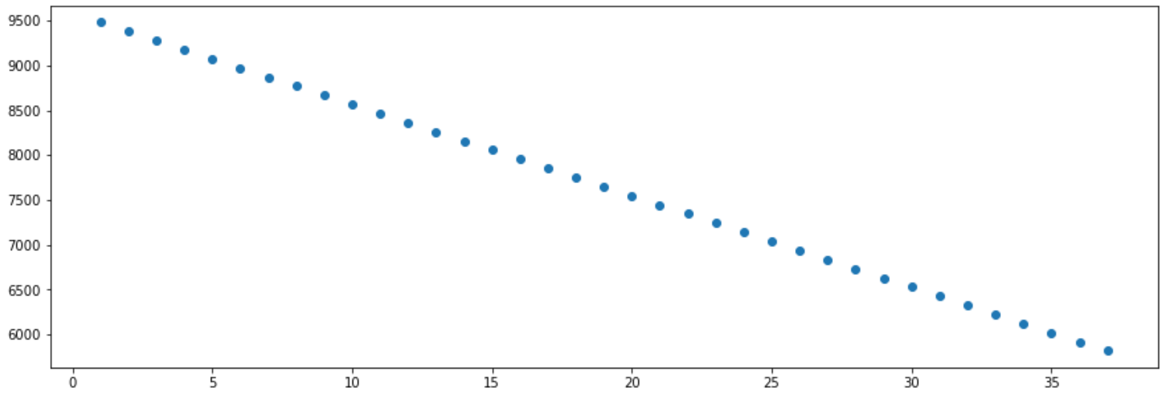
In [85]:

```
%%time

x_x=sorted_df1['Order']
y_y=sorted_df1['Vaccine']

predict=model.predict(x_x.values.reshape(-1,1))
plt.figure(figsize=(15,5))
plt.scatter(x_x,predict)
```

```
Wall time: 52 ms
```

Out[85]:

```
<matplotlib.collections.PathCollection at 0x26c8425f370>
```



In [86]:

```
from sklearn.model_selection import KFold
from sklearn.model_selection import cross_val_score
```

In [87]:

```
k = 3
kf = KFold(n_splits=k, random_state=None)
model = LinearRegression()

result = cross_val_score(model, x_x.values.reshape(-1,1), y_y, cv = kf)

print("Avg accuracy: {}".format(result.mean()))
```

```
Avg accuracy: -31.23331466641194
```

In [92]:

```
from sklearn.metrics import mean_squared_error
MSE = np.square(np.subtract(y_y,predict)).mean()
print(MSE)
```

```
33950313.698332764
```

In [93]:

```
#regression on 2nd dose
```

In [94]:

```
%%time

x1=df2t['report_date']
y1=df2t['previous_day_fully_vaccinated']

x_train1, x_test1, y_train1, y_test1 = train_test_split(x1, y1, test_size=0.3
```

```
Wall time: 1.92 ms
```

In [95]:

```
%%time

#create dataframe from trained data
report_date=x_train1
f_vax=y_train1
zipped = list(zip(report_date,f_vax))

temp_df = pd.DataFrame(zipped, columns=['Report_Date', 'Vaccine'])
sorted_df2 = temp_df.sort_values(by='Report_Date')
```

```
Wall time: 3 ms
```

In [96]:

```
%%time

#add ordinal value for date
l=[]
for i in range(len(sorted_df2['Report_Date'])):
    i+=1
    l.append(i)
sorted_df2['Order']=l
```

```
Wall time: 1 ms
```

In [97]:

```
%%time

model=LinearRegression()
xx=sorted_df2['Order']
yy=sorted_df2['Vaccine']

model.fit(xx.values.reshape(-1,1),yy)
a=model.coef_
print("slope:"+ str(a))
b=model.intercept_
print("intercept:"+str(b))
print("model score:"+str(model.score(xx.values.reshape(-1,1),yy)))
```

```
slope:[195.53860835]
intercept:1171.9288738738755
model score:0.424132779257246
Wall time: 4 ms
```

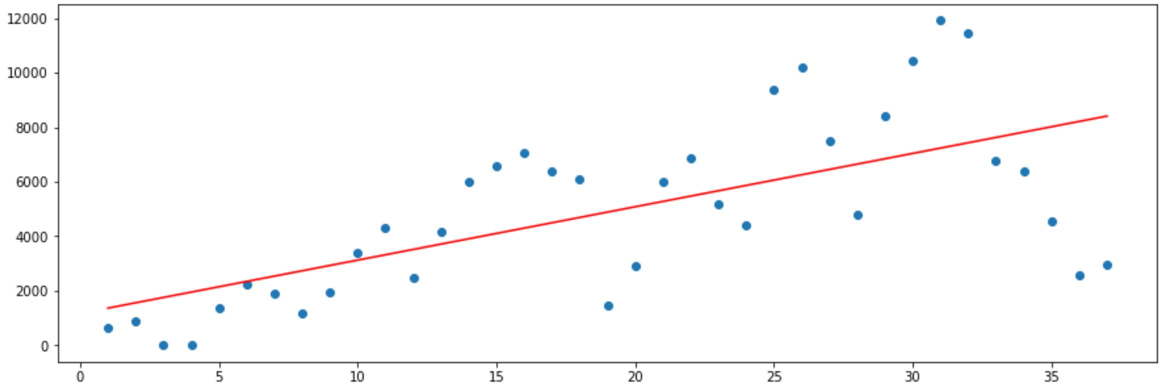
In [98]:

```
%%time

xx=sorted_df2['Order']
yy=sorted_df2['Vaccine']
plt.figure(figsize=(15,5))
plt.scatter(xx,yy)
a, b = np.polyfit(xx, yy, 1)
plt.plot(xx, a*xx+b, color='red')
```

```
Wall time: 34 ms
```

Out[98]:

```
[<matplotlib.lines.Line2D at 0x26c8465e8e0>]
```



In [99]:

```
%%time

#sorted test dataframe
report_date1=x_test1
f_vax1=y_test1
zipped = list(zip(report_date1,f_vax1))

temp_df1 = pd.DataFrame(zipped, columns=['Report_Date', 'Vaccine'])
sorted_df1 = temp_df.sort_values(by='Report_Date')
```

```
Wall time: 2 ms
```

In [100]:

```
%%time

#add ordinal value for date
l1=[]
for i in range(len(sorted_df1['Report_Date'])):
    i+=1
    l1.append(i)
sorted_df1['Order']=l1
```

```
Wall time: 2 ms
```

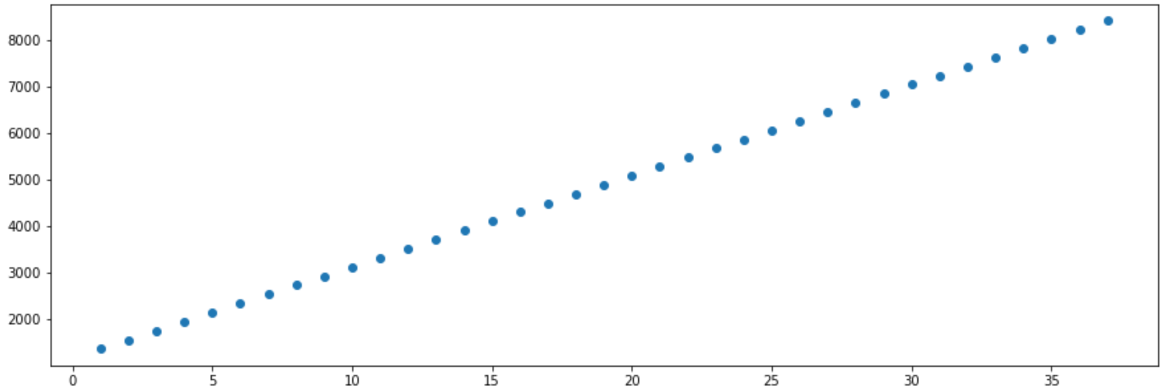
In [101]:

```
%%time

x_x=sorted_df2['Order']
y_y=sorted_df2['Vaccine']

predict=model.predict(x_x.values.reshape(-1,1))
plt.figure(figsize=(15,5))
plt.scatter(x_x,predict)
```

```
Wall time: 25 ms
```

Out[101]:

```
<matplotlib.collections.PathCollection at 0x26c84845b80>
```



In [102]:

```
from sklearn.model_selection import KFold
from sklearn.model_selection import cross_val_score
```

In [103]:

```
k = 3
kf = KFold(n_splits=k, random_state=None)
model = LinearRegression()

result = cross_val_score(model, x_x.values.reshape(-1,1), y_y, cv = kf)

print("Avg accuracy: {}".format(result.mean()))
```

```
Avg accuracy: -2.952632806470035
```

In [104]:

```
from sklearn.metrics import mean_squared_error
MSE = np.square(np.subtract(y_y,predict)).mean()
print(MSE)
```

```
5918210.544500327
```

In [105]:

```
#regression on 3rd dose
```

In [106]:

```
%%time

x2=df3['report_date']
y2=df3['previous_day_3doses']

x_train2, x_test2, y_train2, y_test2 = train_test_split(x2, y2, test_size=0.3
```

```
Wall time: 2 ms
```

In [107]:

```
%%time

#create dataframe from trained data
report_date=x_train2
f_vax=y_train2
zipped = list(zip(report_date,f_vax))

temp_df = pd.DataFrame(zipped, columns=['Report_Date', 'Vaccine'])
sorted_df3 = temp_df.sort_values(by='Report_Date')
```

```
Wall time: 3 ms
```

In [108]:

```
%%time

#add ordinal value for date
l=[]
for i in range(len(sorted_df3['Report_Date'])):
    i+=1
    l.append(i)
sorted_df3['Order']=l
```

```
Wall time: 1 ms
```

In [109]:

```
%%time

model=LinearRegression()
xx=sorted_df3['Order']
yy=sorted_df3['Vaccine']

model.fit(xx.values.reshape(-1,1),yy)
a=model.coef_
print("slope:"+ str(a))
b=model.intercept_
print("intercept:"+str(b))
print("model score:"+str(model.score(xx.values.reshape(-1,1),yy)))
```

```
slope:[-4306.32906591]
intercept:144458.49549549547
model score:0.800142426663579
Wall time: 3 ms
```

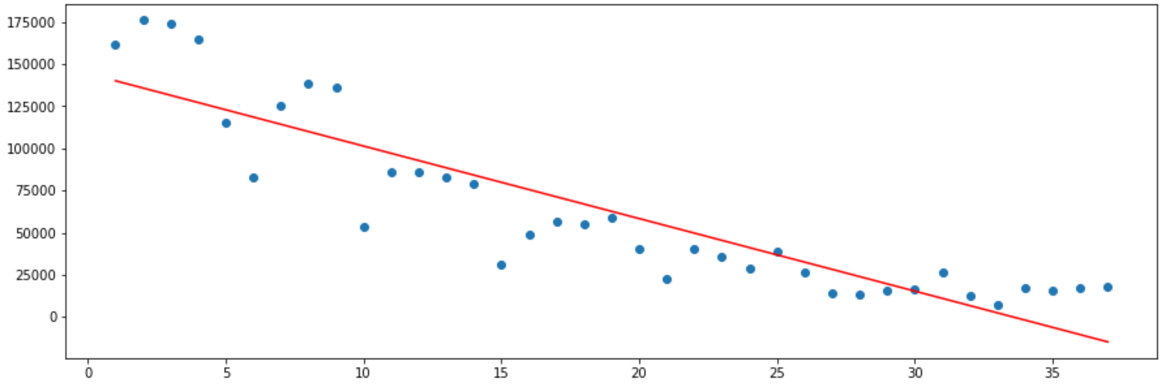
In [110]:

```
%%time

xx=sorted_df3['Order']
yy=sorted_df3['Vaccine']
plt.title('3rd Dose train data regression')
plt.figure(figsize=(15,5))
plt.scatter(xx,yy)
a, b = np.polyfit(xx, yy, 1)
plt.plot(xx, a*xx+b, color='red')
```

```
Wall time: 51 ms
```

Out[110]:

```
[<matplotlib.lines.Line2D at 0x26c84973730>]
```



In [111]:

```
%%time

#sorted test dataframe
report_date1=x_test2
f_vax1=y_test2
zipped = list(zip(report_date1,f_vax1))

temp_df1 = pd.DataFrame(zipped, columns=['Report_Date', 'Vaccine'])
sorted_df1 = temp_df.sort_values(by='Report_Date')
```

```
Wall time: 6 ms
```

In [112]:

```
%%time

#add ordinal value for date
l1=[]
for i in range(len(sorted_df3['Report_Date'])):
    i+=1
    l1.append(i)
sorted_df1['Order']=l1
```

```
Wall time: 1 ms
```

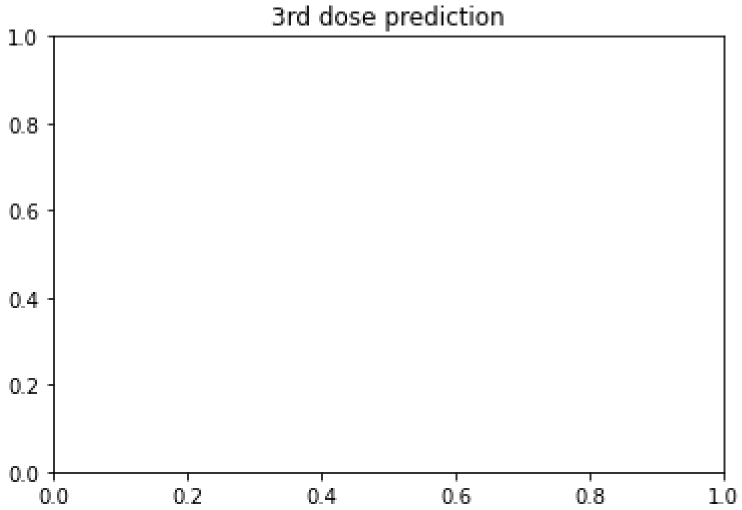
In [113]:

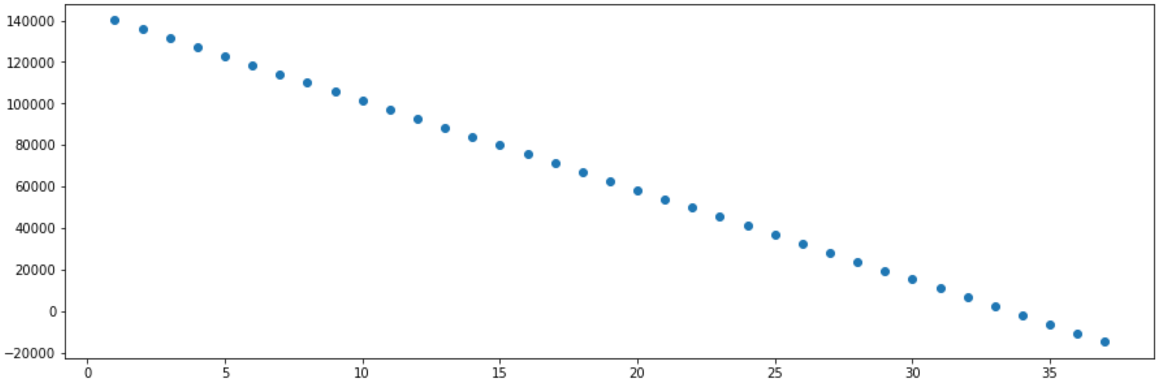
```
%%time

x_x=sorted_df1['Order']
y_y=sorted_df1['Vaccine']

predict=model.predict(x_x.values.reshape(-1,1))
plt.title('3rd dose prediction')
plt.figure(figsize=(15,5))
plt.scatter(x_x,predict)
```

```
Wall time: 44 ms
```

Out[113]:

```
<matplotlib.collections.PathCollection at 0x26c84b68160>
```





In [114]:

```
#cross validation
```

In [115]:

```
from sklearn.model_selection import KFold
from sklearn.model_selection import cross_val_score
```

In [116]:

```
k = 3
kf = KFold(n_splits=k, random_state=None)
model = LinearRegression()

result = cross_val_score(model, x_x.values.reshape(-1,1), y_y, cv = kf)

print("Avg accuracy: {}".format(result.mean()))
```

```
Avg accuracy: -30.11483095572689
```

In [118]:

```
from sklearn.metrics import mean_squared_error
MSE = np.square(np.subtract(y_y,predict)).mean()
print(MSE)
```

```
528047010.86668456
```

In [119]:

```
#Gradient Boosting Regressor
```

In [120]:

```
from sklearn.ensemble import GradientBoostingRegressor
from sklearn.metrics import mean_squared_error
```

In [121]:

```
%%time

x2=df3['report_date']
y2=df3['previous_day_3doses']

x_train, x_test, y_train, y_test = train_test_split(x2, y2, test_size=0.3)
```

```
Wall time: 2 ms
```

In [122]:

```
%%time

from sklearn.preprocessing import StandardScaler
tx=x_train
xt=x_test
ty=y_train
sc = StandardScaler()

X_train_std = sc.fit_transform(tx.values.reshape(-1,1))
X_test_std = sc.transform(xt.values.reshape(-1,1))
```

```
Wall time: 1 ms
```

In [123]:

```
%%time

gbr_params = {'n_estimators': 100,
          'max_depth': 3,
          'min_samples_split': 2,
          'learning_rate': 0.1,
          }
```

```
Wall time: 0 ns
```

In [124]:

```
%%time
gbr = GradientBoostingRegressor(**gbr_params)
```

```
Wall time: 0 ns
```

In [125]:

```
%%time
gbr.fit(X_train_std, y_train)
```

```
Wall time: 59 ms
```

Out[125]:

```
GradientBoostingRegressor()
```

In [126]:

```
print("Model Accuracy: %.3f" % gbr.score(X_test_std, y_test))
```

```
Model Accuracy: 0.915
```

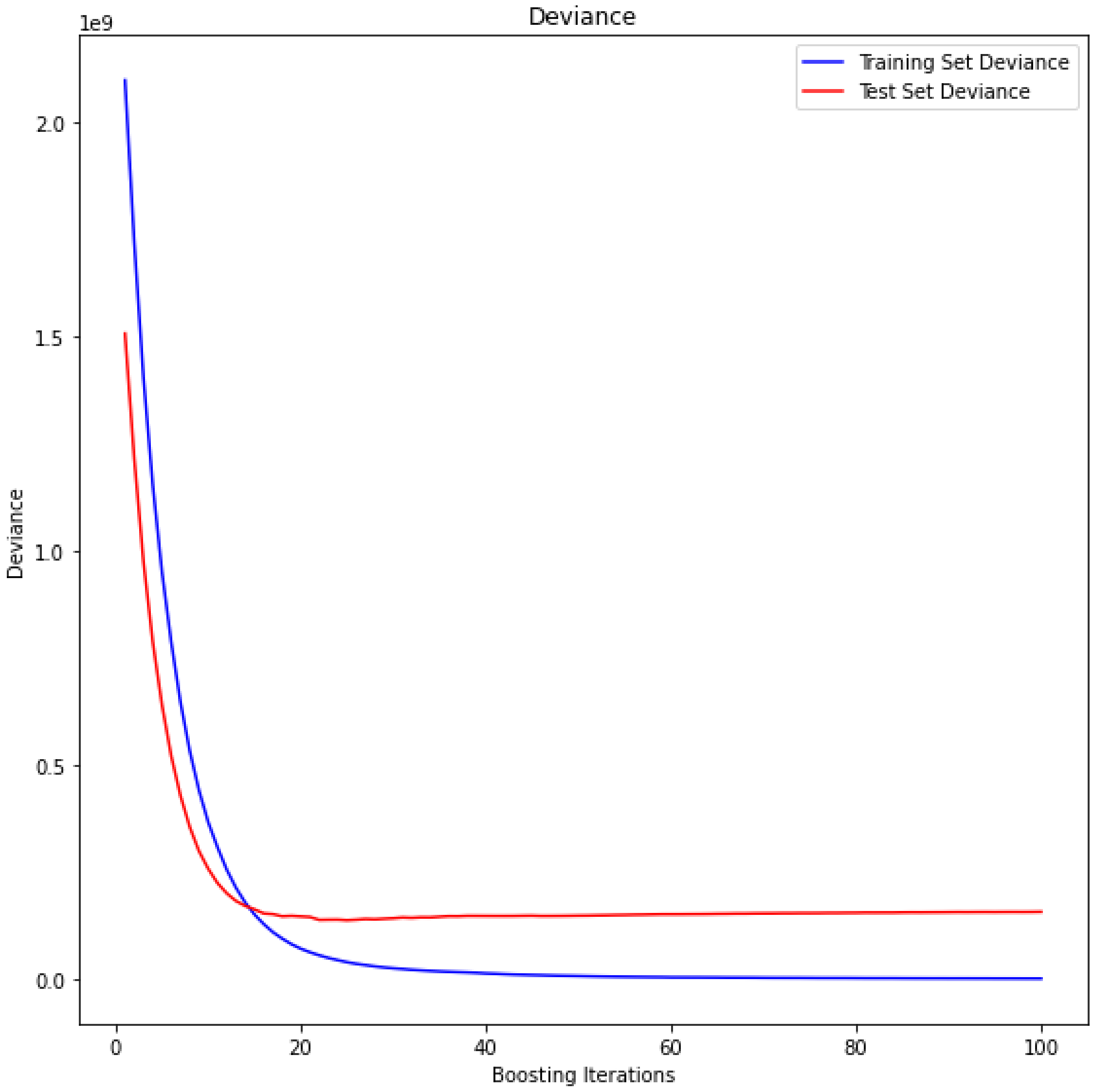
In [127]:

```
%%time
mse = mean_squared_error(y_test, gbr.predict(X_test_std))
print("The mean squared error (MSE) on test set: {:.4f}".format(mse))
```

```
The mean squared error (MSE) on test set: 156854677.1496
Wall time: 1 ms
```

In [128]:

```
%%time
test_score = np.zeros((gbr_params['n_estimators'],), dtype=np.float64)
for i, y_pred in enumerate(gbr.staged_predict(X_test_std)):
    test_score[i] = gbr.loss_(y_test, y_pred)

fig = plt.figure(figsize=(8, 8))
plt.subplot(1, 1, 1)
plt.title('Deviance')
plt.plot(np.arange(gbr_params['n_estimators']) + 1, gbr.train_score_, 'b-',
         label='Training Set Deviance')
plt.plot(np.arange(gbr_params['n_estimators']) + 1, test_score, 'r-',
         label='Test Set Deviance')
plt.legend(loc='upper right')
plt.xlabel('Boosting Iterations')
plt.ylabel('Deviance')
fig.tight_layout()
plt.show()
```



```
Wall time: 748 ms
```

In [129]:

```
#cross validation
```

In [130]:

```
from sklearn.model_selection import KFold
from sklearn.model_selection import cross_val_score
```

In [131]:

```
k = 3
kf = KFold(n_splits=k, random_state=None)
model = gbr

result = cross_val_score(model , x_train.values.reshape(-1,1), y_train, cv =

print("Avg accuracy: {}".format(result.mean()))
```

```
Avg accuracy: 0.6880104485754818
```