DAV Mini Project

Covid-19 Data analysis & Forecasting

Citation

Analyzing the epidemiological outbreak of COVID-19: A visual exploratory data analysis approach

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Dataset description

Datasets

Dataset link

The project utilized four primary datasets acquired from Kaggle specifically tailored for Covid-19 Data Analysis & Forecasting. These datasets include:

`covid.csv` : Contains daily case updates, including state-specific case and death counts. `owid-covid-data.csv` : Offers comprehensive global Covid-19 data by Our World in Data, which includes testing rates and outcomes for various countries, with a focus on the United States for this analysis. `pop_data.csv` : Provides population data, crucial for calculating per capita statistics and understanding the impact relative to the size of the population. `recovered.csv` : Tracks the number of recovered Covid-19 patients, essential for assessing recovery rates and outcomes.

Models Used and Parameters

The project leverages Facebook's Prophet model for predictive analysis. Prophet is chosen for its ability to handle the time series data of Covid-19 cases, recognizing trends and seasonality in the dataset. The model's default parameters were primarily used, with specific attention to:

Seasonality: Incorporated to account for weekly and yearly trends observed in the data, acknowledging the cyclic nature of case reports and testing rates. Change Points: Allowed Prophet to detect points of significant change in the trend, accommodating for sudden increases or decreases in case numbers.

Summary

The analysis embarked on a comprehensive examination of Covid-19's spread across the United States, employing visualizations to depict the proliferation of cases and deaths over time and across different states. It further investigated the testing strategy in the U.S. through daily and cumulative testing figures, alongside the positivity rate and tests per case metrics. Additionally, the study explored the potential political affiliation impact on case rates, differentiating between Democratic and Republican states.

Result and Findings

The analysis of Covid-19's impact and response in the United States yielded several key findings:

Geographical Variation : The spread of Covid-19 showed significant variation across states. Visualization tools underscored the virus's progression over time, highlighting states with higher infection rates per capita.

Testing Analysis: Examination of testing data revealed fluctuations in daily testing numbers. An observed increase in the positivity rate at certain times suggested periods of heightened virus transmission.

Predictive Modeling: Using the Prophet model, the project forecasted future case numbers. This provided insights into potential trends and the effectiveness of ongoing public health measures.

Political Affiliation Impact : The analysis indicates Democratic states have a higher Covid-19 infection rate (0.6%) compared to Republican states (0.44%). This discrepancy could be attributed to several factors:

Urbanization : Democratic states often have denser urban populations, facilitating quicker virus spread. Testing Rates: Increased testing in Democratic states might lead to higher detected case rates. Policy Responses: Divergent public health policies between states could influence transmission rates. It's crucial to recognize these findings reflect correlations within the analyzed data and are influenced by complex, multifactorial dynamics, rather than suggesting direct causality.

Comparative study

Comparative Analysis of COVID-19 Data Projects

Scope

- **Our Project:**
    - Focuses on a specific region, forecasting COVID-19's spread.
    - Examines the role of political affiliations in pandemic trajectory.
- **The Reviewed Project:**
    - Offers a global perspective, with emphasis on China.
    - Aims to enhance situational awareness through visual exploratory data analysis (EDA).

Data Analysis

- **Our Project:**
    - Utilizes predictive modeling, notably the Prophet model.
    - Explores how sociopolitical dynamics influence pandemic patterns.
- **The Reviewed Project:**
    - Relies on visual EDA to map pandemic spread.
    - Prioritizes data clarity through visual representations.

Findings

- **Our Project:**
    - Illuminates forthcoming pandemic trends.
    - Scrutinizes pandemic spread within political landscapes.
- **The Reviewed Project:**
    - Highlights geographical and chronological spread, particularly in Hubei province.
    - Examines global ramifications of COVID-19 outbreak.

Contributions

- **Our Project:**
    - Offers predictive insights into pandemic's future course.
    - Examines nuanced impact of political factors.
- **The Reviewed Project:**
    - Makes epidemiological data accessible and interpretable through visual means.
    - Supports early containment efforts.

Summary

While both projects aim to analyze COVID-19 data, ours leans towards predictive analysis and examination of political affiliations. In contrast, the reviewed project focuses on visually presenting early-stage pandemic data, particularly emphasizing the initial outbreak period.

Implementation

```
!gdown --id 1zsWysPCm6AWls0K4tA-2rVLgohO2g8NQ
```

```
/usr/local/lib/python3.10/dist-packages/gdown/cli.py:138: FutureWarning: Option `--i
  warnings.warn(
Downloading...
From: https://drive.google.com/uc?id=1zsWysPCm6AWls0K4tA-2rVLgohO2g8NQ
To: /content/archive.zip
100% 938k/938k [00:00<00:00, 103MB/s]
```

```
!mkdir data
!unzip archive.zip -d data
```

```
Archive:  archive.zip
  inflating: data/covid.csv
  inflating: data/owid-covid-data.csv
  inflating: data/pop_data.csv
  inflating: data/recovered.csv
```

```
%%capture
!pip install prophet
```

```
import pandas as pd
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
import numpy as np
import seaborn as sns
import warnings
# warnings.filterwarnings('ignore')
import seaborn as sns
import plotly.express as px
from datetime import datetime as dt
from datetime import timedelta
#from pytrends.request import TrendReq
from prophet import Prophet
```

```
# get data
data = pd.read_csv(r'data/covid.csv', error_bad_lines = False)

recovered = pd.read_csv(r'data/recovered.csv', error_bad_lines = False)
recovered.columns = ['date', 'Recovered']
recovered.index = pd.to_datetime(recovered['date'])
recovered = recovered['Recovered'].astype('int64')
```

```
<ipython-input-17-7e213232686d>:2: FutureWarning: The error_bad_lines argument has b


  data = pd.read_csv(r'data/covid.csv', error_bad_lines = False)
<ipython-input-17-7e213232686d>:4: FutureWarning: The error_bad_lines argument has b
```

```
  recovered = pd.read_csv(r'data/recovered.csv', error_bad_lines = False)
date
2020-01-22          0
2020-01-23          0
2020-01-24          0
2020-01-25          0
2020-01-26          0
                 ...
2020-08-04    1528979
2020-08-05    1577851
2020-08-06    1598624
2020-08-07    1623870
2020-08-08    1643118
Name: Recovered, Length: 200, dtype: int64
```

```
data
```

	Unnamed: 0	date	state	fips	cases	deaths
0	0	2020-01-21	Washington	53	1	0
1	1	2020-01-22	Washington	53	1	0
2	2	2020-01-23	Washington	53	1	0
3	3	2020-01-24	Illinois	17	1	0
4	4	2020-01-24	Washington	53	1	0
...	...	...	...	...	...	...
8754	8754	2020-08-08	Virginia	51	99189	2322
8755	8755	2020-08-08	Washington	53	64347	1752
8756	8756	2020-08-08	West Virginia	54	7563	131
8757	8757	2020-08-08	Wisconsin	55	64231	1007
8758	8758	2020-08-08	Wyoming	56	3013	28

8759 rows × 6 columns

```
# clean dataframes
data.drop('Unnamed: 0',axis = 1, inplace = True)
```

```
cases = data[['date', 'state', 'cases', 'deaths']]
```

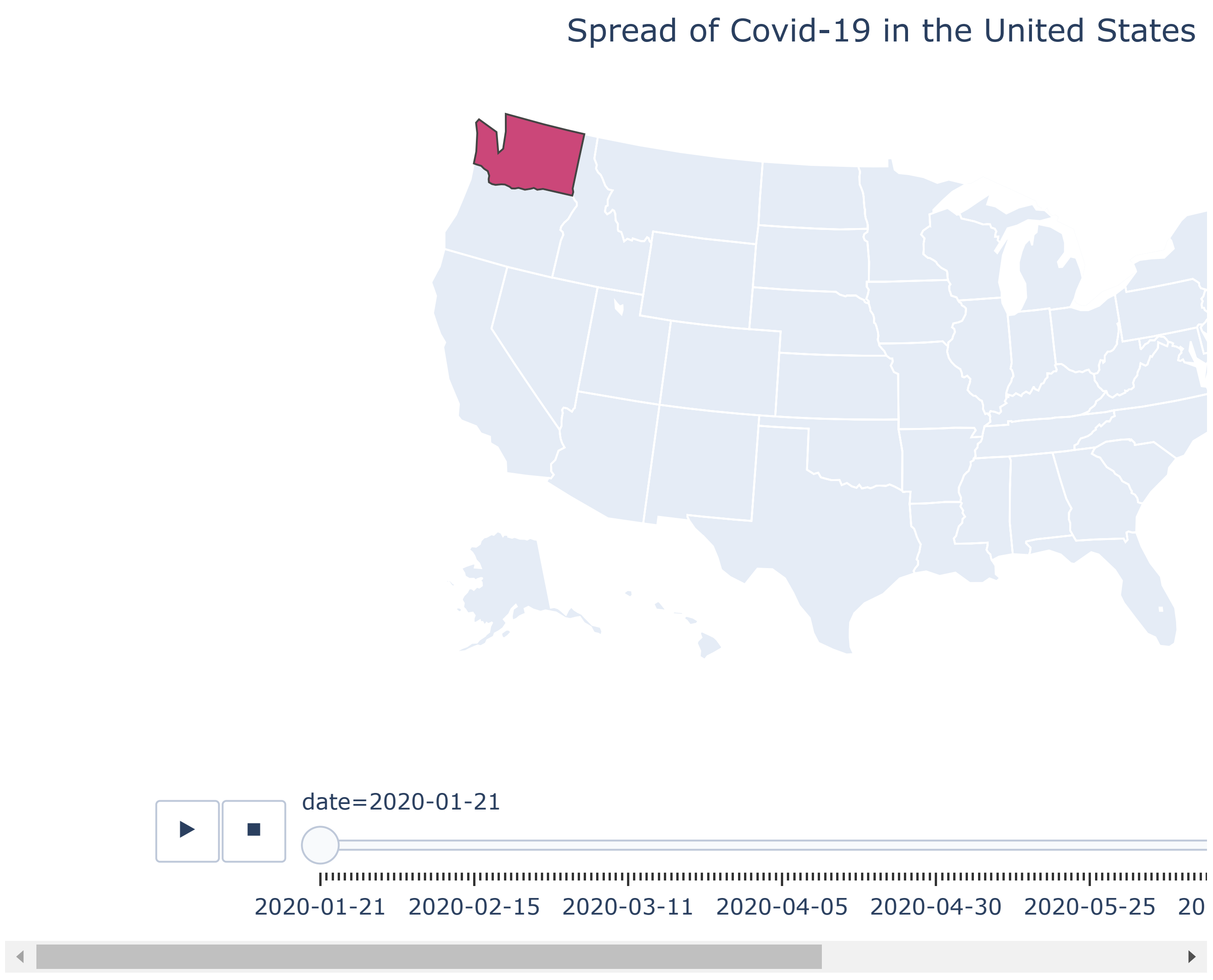
```
    us_states = {
            'Alaska': 'AK',
            'Alabama': 'AL',
            'Arkansas': 'AR',
            'American Somoa': 'AS',
            'Arizona': 'AZ',
            'California': 'CA',
            'Colorado': 'CO',
            'Connecticut': 'CT',
            'District of Colombia': 'DC',
            'Delaware': 'DE',
            'Florida': 'FL',
            'Georgia': 'GA',
            'Hawaii': 'HI',
            'Iowa': 'IA',
            'Idaho': 'ID',
            'Illinois': 'IL',
            'Indiana': 'IN',
            'Kansas': 'KS',
            'Kentucky': 'KY',
            'Louisiana': 'LA',
            'Massachusetts': 'MA',
            'Maryland': 'MD',
            'Maine': 'ME',
            'Michigan': 'MI',
            'Minnesota': 'MN',
            'Missouri': 'MO',
            'Mississippi': 'MS',
            'Montana': 'MT',
            'National': 'NA',
            'North Carolina': 'NC',
            'North Dakota': 'ND',
            'Nebraska': 'NE',
            'New Hampshire': 'NH',
            'New Jersey': 'NJ',
            'New Mexico': 'NM',
            'Nevada': 'NV',
            'New York': 'NY',
            'Ohio': 'OH',
            'Oklahoma': 'OK',
            'Oregon': 'OR',
            'Pennsylvania': 'PA',
            'Puerto Rico': 'PR',
            'Rhode Island': 'RI',
            'South Carolina': 'SC',
            'South Dakota': 'SD',
            'Tennessee': 'TN',
            'Texas': 'TX',
            'Utah': 'UT',
            'Virginia': 'VA',
            'Virgin Islands': 'VI',
            'Vermont': 'VT',
            'Washington': 'WA',
            'Wisconsin': 'WI',
            'West Virginia': 'WV',
            'Wyoming': 'WY'
    }


    cases['abbrev'] = cases['state'].map(us_states).fillna(cases['state'])
    cases
```

	date	state	cases	deaths	abbrev
0	2020-01-21	Washington	1	0	WA
1	2020-01-22	Washington	1	0	WA
2	2020-01-23	Washington	1	0	WA
3	2020-01-24	Illinois	1	0	IL
4	2020-01-24	Washington	1	0	WA
...	...	...	...	...	...
8754	2020-08-08	Virginia	99189	2322	VA
8755	2020-08-08	Washington	64347	1752	WA
8756	2020-08-08	West Virginia	7563	131	WV
8757	2020-08-08	Wisconsin	64231	1007	WI
8758	2020-08-08	Wyoming	3013	28	WY

8759 rows × 5 columns

Great, we have added abbreviations to the dataframe. We will keep the state name for ease of use when merging another dataframe. Now we can plot a geographical visual that tells us the prevalence of cases in each state over a certain time period.

```
fig = px.choropleth(cases,
                   locations='abbrev',
                   color='cases',
                   hover_name = 'abbrev',
                   locationmode = 'USA-states',
                   animation_frame = 'date')

fig.update_layout(
title_text = 'Spread of Covid-19 in the United States',
title_x = 0.5,
geo_scope = 'usa',
geo=dict(
showframe = False,
showcoastlines = False))

fig.show()
```



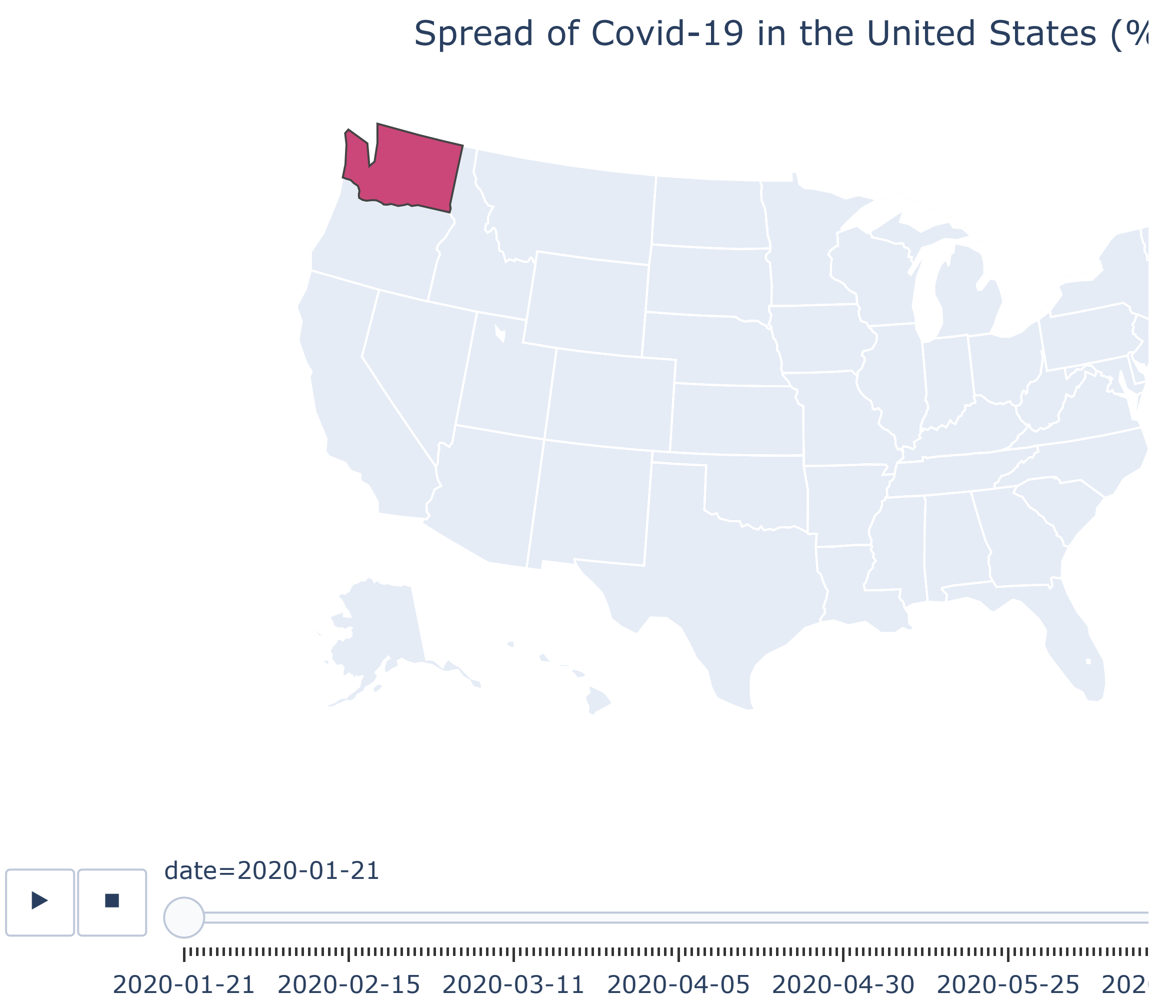
We can see the severity of cases as the virus spreads across the United States with the above visual. However, a more helpful statistic will be to measure the virus spread versus the population for each state. Then we can get a more accurate estimate of the significance it holds in each state.

```
pop_data = pd.read_csv(r'data/pop_data.csv')


#merge population to dataframe.
cases = cases.merge(pop_data,
          how = 'left',
          left_on = 'state',
          right_on = 'state')
cases
```

```
      date        state         cases  deaths  abbrev  Unnamed: 0  population
0     2020-01-21  Washington    1      0       WA      12.0        7614893.0
1     2020-01-22  Washington    1      0       WA      12.0        7614893.0
2     2020-01-23  Washington    1      0       WA      12.0        7614893.0
3     2020-01-24  Illinois      1      0       IL      4.0         12671821.0
4     2020-01-24  Washington    1      0       WA      12.0        7614893.0
...   ...         ...           ...    ...     ...     ...         ...
8754  2020-08-08  Virginia      99189  2322    VA      11.0        8535519.0
8755  2020-08-08  Washington    64347  1752    WA      12.0        7614893.0
8756  2020-08-08  West Virginia 7563   131     WV      37.0        1792147.0
8757  2020-08-08  Wisconsin     64231  1007    WI      19.0        5822434.0
8758  2020-08-08  Wyoming       3013   28      WY      50.0        578759.0

8759 rows × 7 columns
```

Now that we have a more complete dataframe we will create another visual to account for the severity of cases in each state. To do this we will use the same as above for simplicity. First, we must determine a rolling percentage of cases in each state so that we can determine the severity of the virus.

```
#creating percentage column in dataframe.
cases['percent'] = cases['cases'] / cases['population'] * 100


fig = px.choropleth(cases,
                   locations='abbrev',
                   color='percent',
                   hover_name = 'abbrev',
                   locationmode = 'USA-states',
                   animation_frame = 'date')

fig.update_layout(
title_text = 'Spread of Covid-19 in the United States (%)',
title_x = 0.5,
geo_scope = 'usa',
geo=dict(
showframe = False,
showcoastlines = False))

fig.show()
```



In recent months, the percent of population with the virus has increased dramatically. Some states now have over the 2.5% threshold. Yet, New York has managed to minimize the amount of cases despite having a surge of cases early on in the virus.

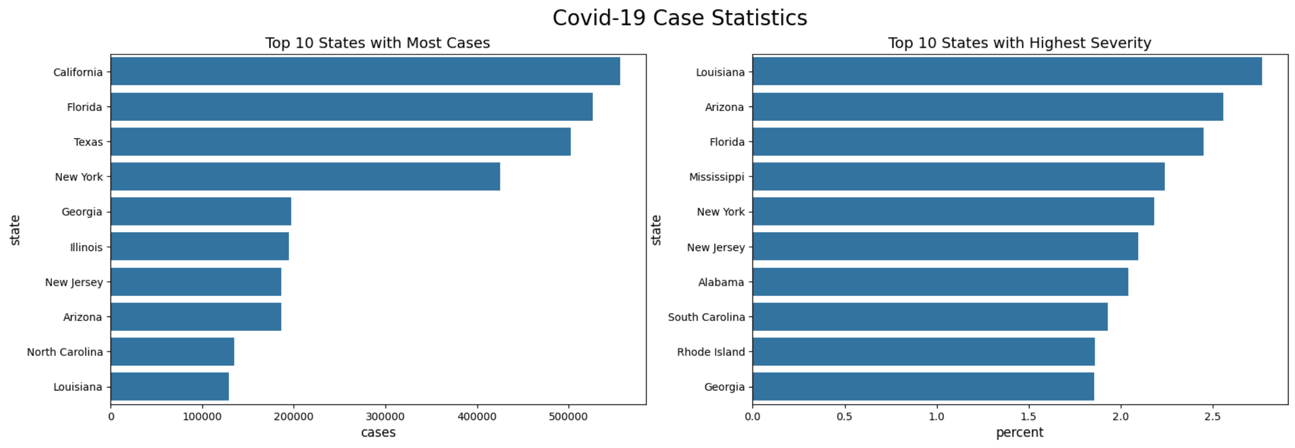
```
sorted_cases = cases.sort_values('cases', ascending=False)
state_max_cases = sorted_cases.drop_duplicates('state')
state_max_cases.drop('abbrev', axis=1, inplace=True)
```

```
<ipython-input-29-ef39a34b3ef9>:3: SettingWithCopyWarning:


A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/u
```

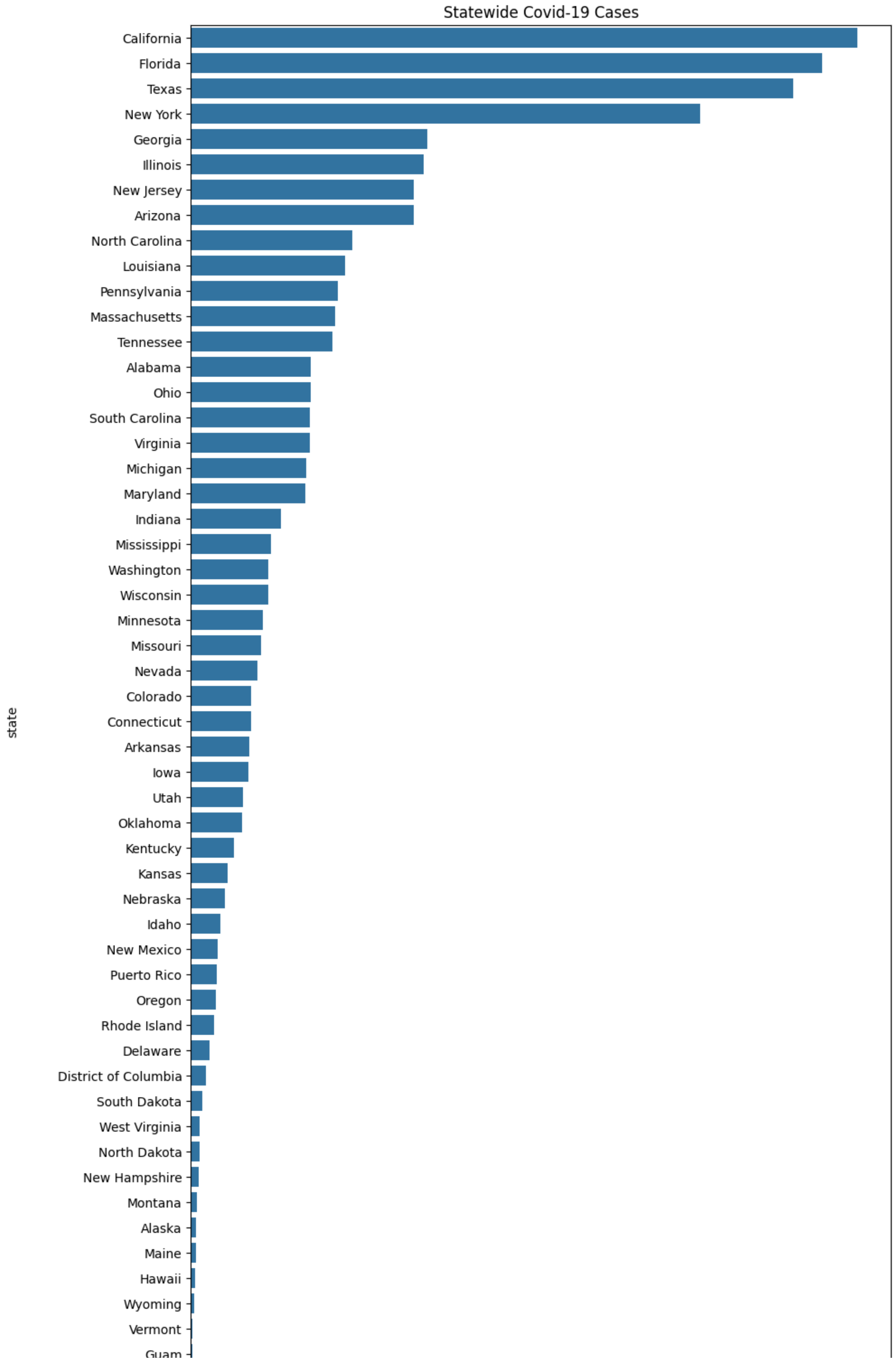
```
#top 10 states with most cases.
cases_top10 = state_max_cases.nlargest(10, 'cases')

#top 10 states with highest severity of cases.
percent_top10 = state_max_cases.nlargest(10, 'percent')
```

```
fig, axes = plt.subplots(1, 2, sharex = False, sharey = False, figsize = (20,6))
fig.suptitle("Covid-19 Case Statistics", fontsize = 20)
axes[0].set_title('Top 10 States with Most Cases', fontsize = 14)
axes[0].set_xlabel('cases', fontsize = 12)
axes[0].set_ylabel('state', fontsize = 12)
axes[1].set_title('Top 10 States with Highest Severity', fontsize = 14)
axes[1].set_xlabel('percent', fontsize = 12)
axes[1].set_ylabel('state', fontsize = 12)

sns.barplot(ax = axes[0], data = cases_top10,
            y = 'state',
            x = 'cases')

sns.barplot(ax = axes[1], data = percent_top10,
            y = 'state',
            x = 'percent')
```

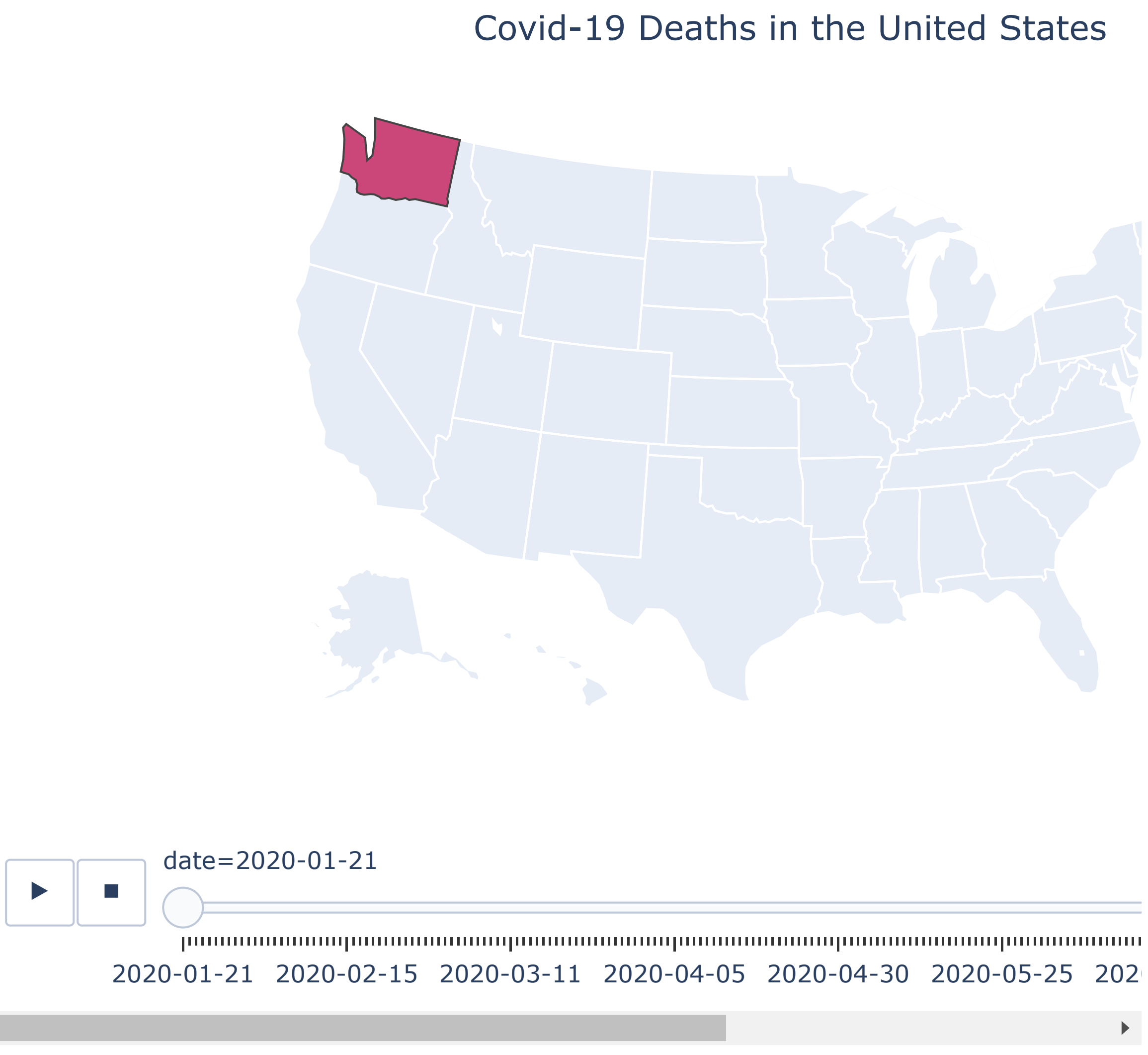
```
<Axes: title={'center': 'Top 10 States with Highest Severity'}, xlabel='percent',
ylabel='state'>
```



```
#add countplot.
fig, ax = plt.subplots(ncols=1, sharey = False, figsize = (10,20))
plt.xticks(rotation=90)
sns.barplot(y = state_max_cases['state'], x = state_max_cases['cases']).set_title('State
Text(0.5, 1.0, 'Statewide Covid-19 Cases')
```



```
#death rate.
percent_deaths = cases['deaths'] / cases['population'] * 100
cases['death rate'] = percent_deaths


#choro map
fig = px.choropleth(cases,
                   locations='abbrev',
                   color='deaths',
                   hover_name = 'abbrev',
                   locationmode = 'USA-states',
                   animation_frame = 'date')

fig.update_layout(
title_text = 'Covid-19 Deaths in the United States',
title_x = 0.5,
geo_scope = 'usa',
geo=dict(
showframe = False,
showcoastlines = False))

fig.show()
```

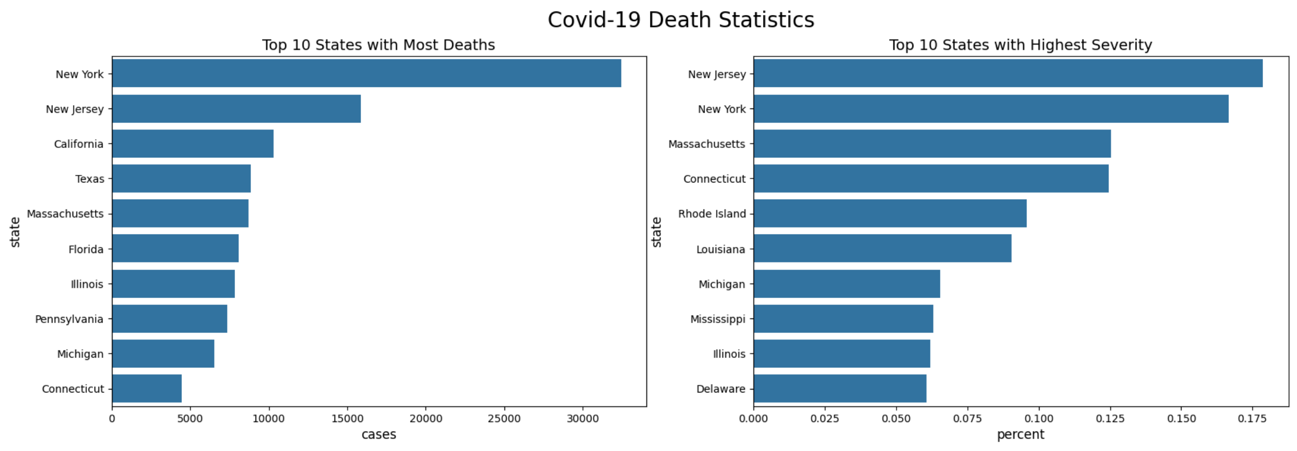


```
sorted_deaths = cases.sort_values('deaths', ascending = False)
state_max_deaths = sorted_deaths.drop_duplicates('state')
state_max_deaths.drop('abbrev', axis=1, inplace=True)
```

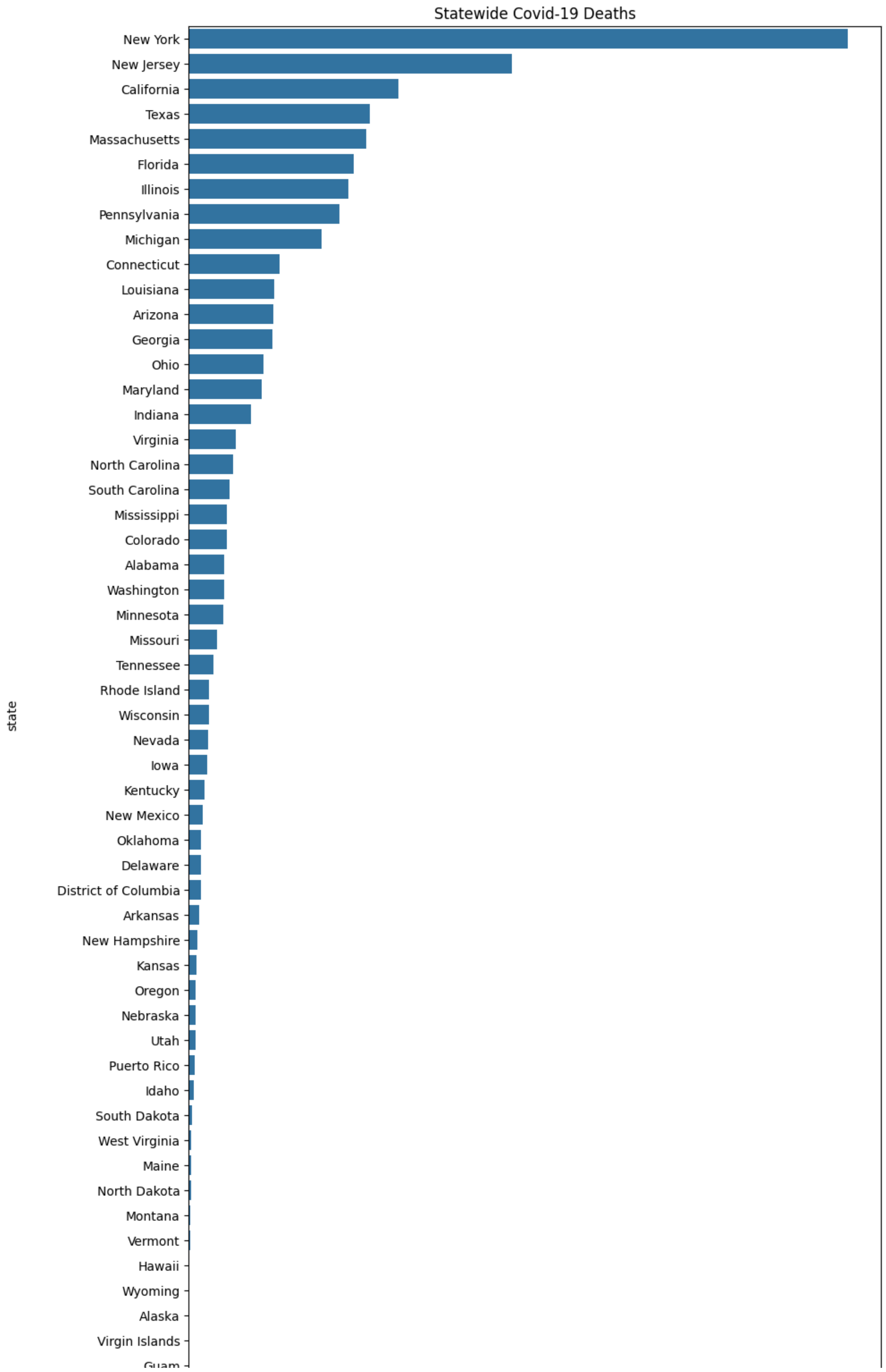
```
<ipython-input-36-6e5eb215e2e2>:3: SettingWithCopyWarning:


A value is trying to be set on a copy of a slice from a DataFrame

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/u
```

```
#top 10 states with most deaths.
deaths_top10 = state_max_deaths.nlargest(10, 'deaths')

#top 10 states with highest death rate.
death_ratetop10 = state_max_deaths.nlargest(10, 'death rate')


fig, axes = plt.subplots(1, 2, sharex = False, sharey = False, figsize = (20,6))
fig.suptitle("Covid-19 Death Statistics", fontsize = 20)
axes[0].set_title('Top 10 States with Most Deaths', fontsize = 14)
axes[0].set_xlabel('cases', fontsize = 12)
axes[0].set_ylabel('state', fontsize = 12)
axes[1].set_title('Top 10 States with Highest Severity', fontsize = 14)
axes[1].set_xlabel('percent', fontsize = 12)
axes[1].set_ylabel('state', fontsize = 12)

sns.barplot(ax = axes[0], data = deaths_top10,
            y = 'state',
            x = 'deaths')

sns.barplot(ax = axes[1], data = death_ratetop10,
            y = 'state',
            x = 'death rate')
```

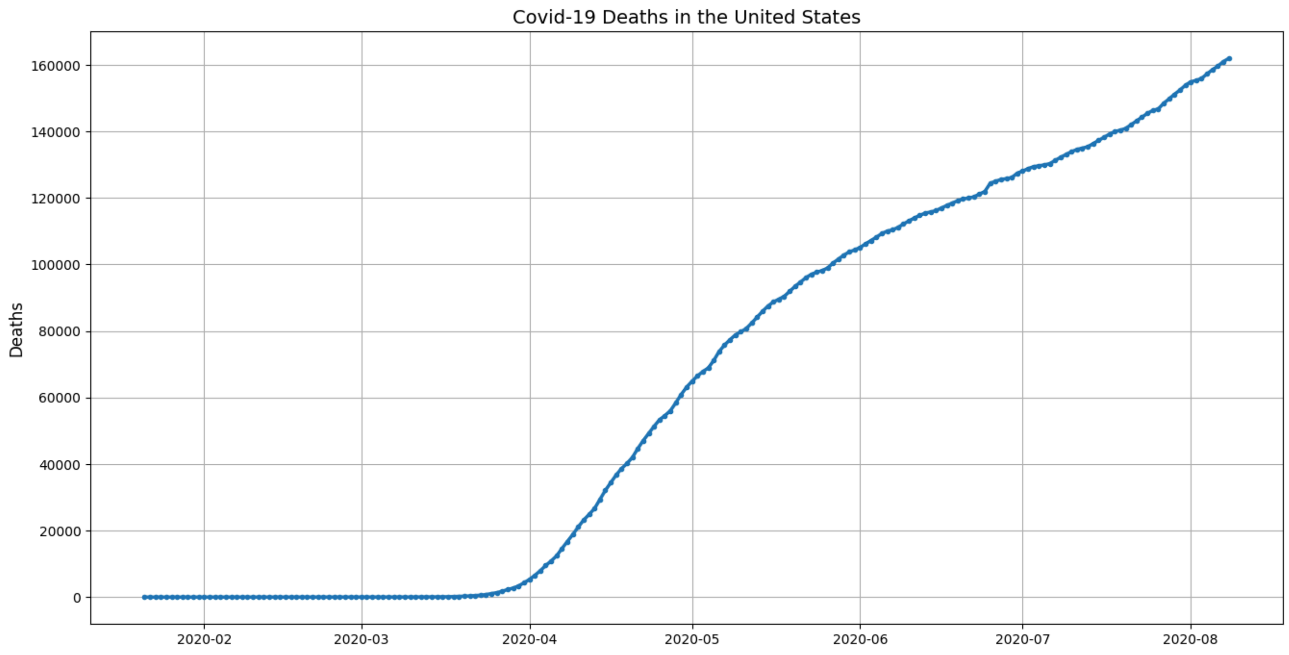
```
<Axes: title={'center': 'Top 10 States with Highest Severity'}, xlabel='percent',
ylabel='state'>
```



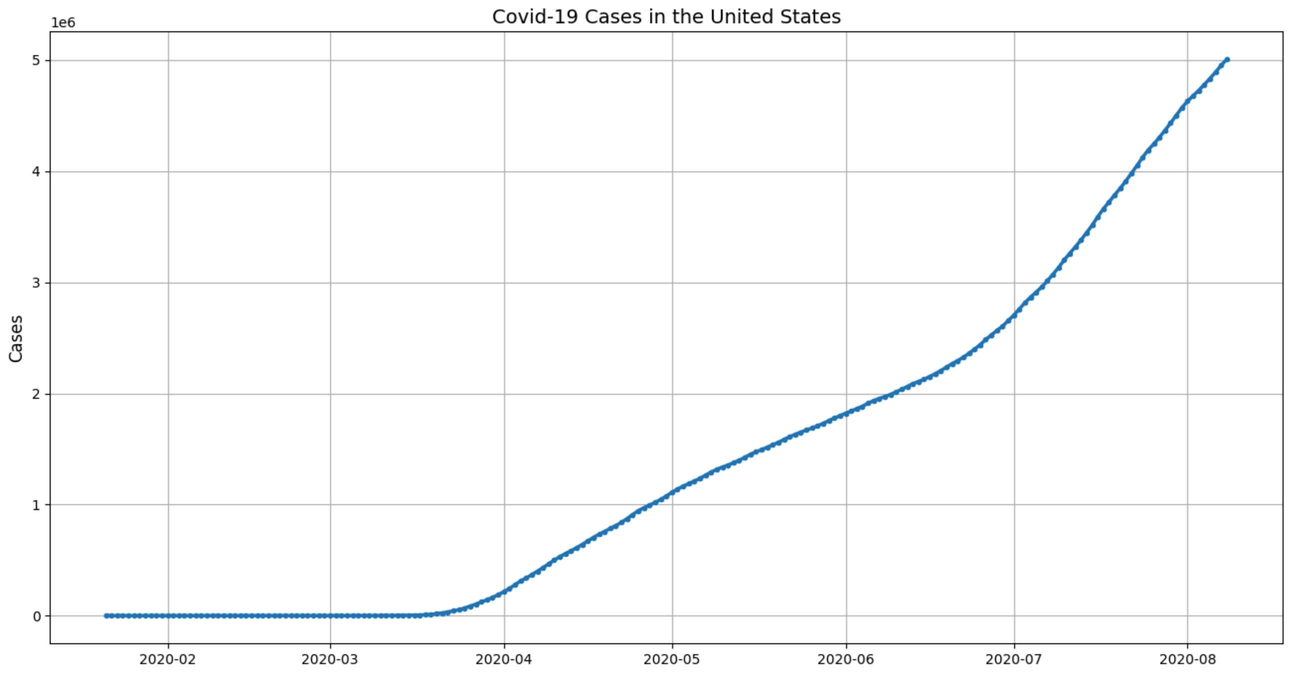
```
#add countplot.
fig, ax = plt.subplots(ncols=1, sharey = False, figsize = (10,20))
plt.xticks(rotation=90)
sortedDeaths = state_max_cases.sort_values(by = ['deaths'], ascending = False)
sns.barplot(y = sortedDeaths['state'], x = sortedDeaths['deaths']).set_title('Statewide
```


Statewide Covid-19 Deaths
state
New York
New Jersey
California
Texas
Massachusetts
Florida
Illinois
Pennsylvania
Michigan
Connecticut
Louisiana
Arizona
Georgia
Ohio
Maryland
Indiana
Virginia
North Carolina
South Carolina
Mississippi
Colorado
Alabama
Washington
Minnesota
Missouri
Tennessee
Rhode Island
Wisconsin
Nevada
Iowa
Kentucky
New Mexico
Oklahoma
Delaware
District of Columbia
Arkansas
New Hampshire
Kansas
Oregon
Nebraska
Utah
Puerto Rico
Idaho
South Dakota
West Virginia
Maine
North Dakota
Montana
Vermont
Hawaii
Wyoming
Alaska
Virgin Islands
Guam

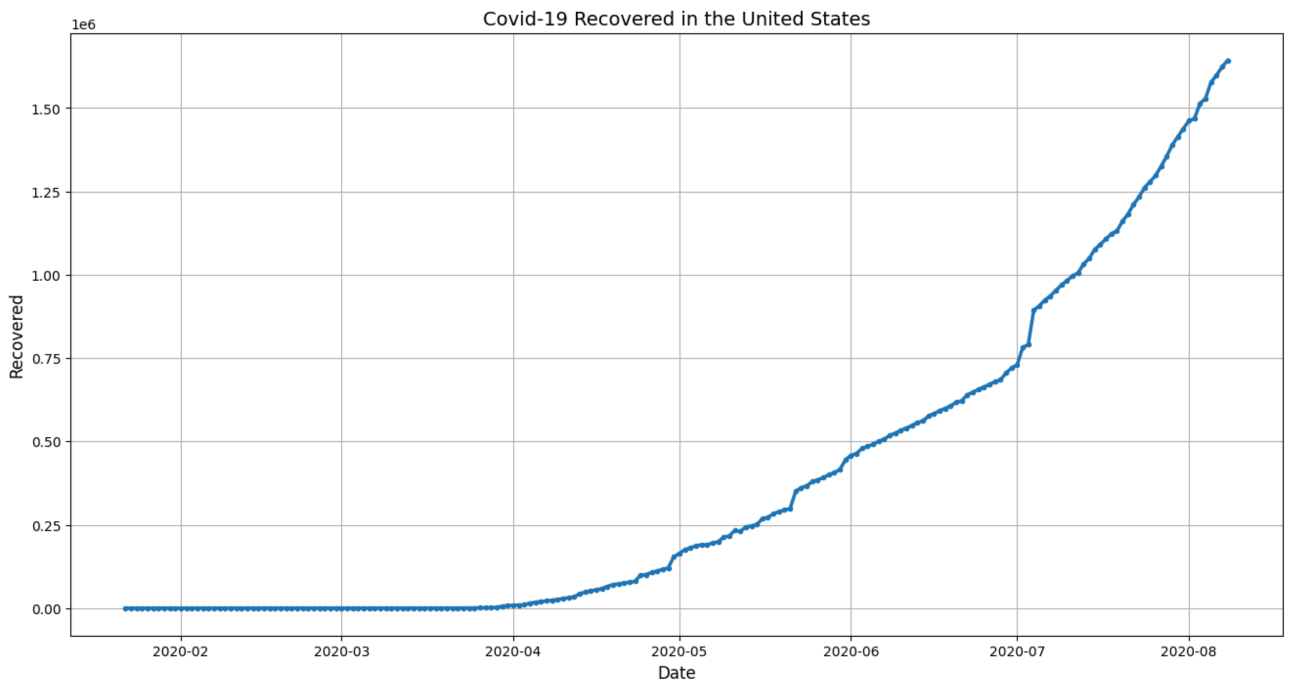
```
date_deaths = data[['date', 'deaths']]
deaths_by_date = date_deaths.groupby('date')['deaths'].sum()

date_cases = data[['date', 'cases']]
cases_by_date = date_cases.groupby('date')['cases'].sum()



deaths_by_date.index = pd.to_datetime(deaths_by_date.index)
months = mdates.MonthLocator()

#plot deaths over time.
fig, ax = plt.subplots(figsize = (16,8))
marker_style = dict(linewidth=2.5, linestyle = '-', marker = 'o', markersize = 3)
ax.plot(deaths_by_date, **marker_style)
plt.ylabel("Deaths", fontsize = 12)
plt.title('Covid-19 Deaths in the United States', fontsize = 14)

#format ticks
ax.xaxis.set_major_locator(months)
ax.grid(True)

plt.show()
```



```
cases_by_date.index = pd.to_datetime(cases_by_date.index)

#plot cases over time.
fig, ax = plt.subplots(figsize = (16,8))
marker_style = dict(linewidth=2.5, linestyle = '-', marker = 'o', markersize = 3)
ax.plot(cases_by_date, **marker_style)
plt.ylabel('Cases', fontsize = 12)
plt.title('Covid-19 Cases in the United States', fontsize = 14)

#formatting
ax.xaxis.set_major_locator(months)
ax.format_xdata = mdates.DateFormatter('%Y-%m-%d')
ax.format_ydata = lambda x: '$%1.2f' % x
ax.grid(True)

plt.show()
```



```
recovered_by_date = pd.DataFrame(recovered)
recovered_by_date.index = pd.to_datetime(recovered_by_date.index)

#plot cases over time.
fig, ax = plt.subplots(figsize = (16,8))
marker_style = dict(linewidth=2.5, linestyle = '-', marker = 'o', markersize = 3)
ax.plot(recovered_by_date, **marker_style)
plt.ylabel('Recovered', fontsize = 12)
plt.xlabel('Date', fontsize = 12)
plt.title('Covid-19 Recovered in the United States', fontsize = 14)

#formatting
ax.xaxis.set_major_locator(months)
ax.format_xdata = mdates.DateFormatter('%Y-%m-%d')
ax.format_ydata = lambda x: '$%1.2f' % x
ax.grid(True)

plt.show()
```

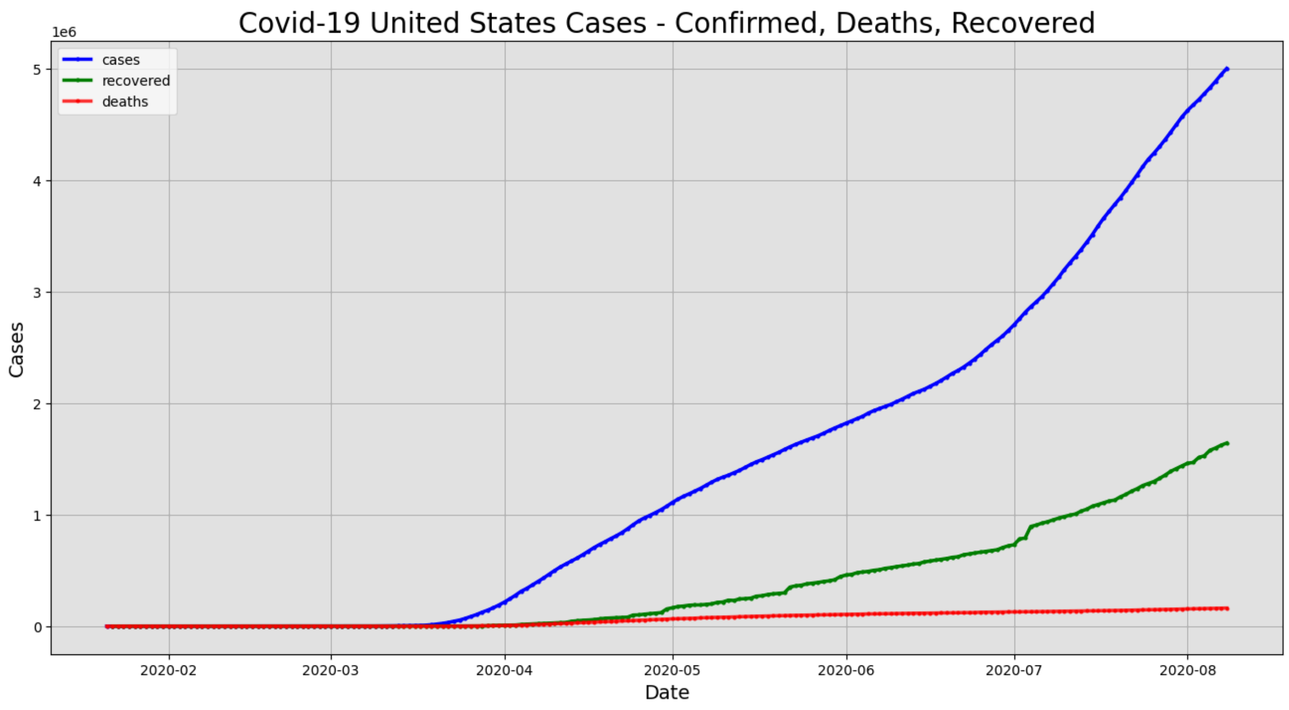


```
#create cleaned dataframe for plot.
recovered.index = pd.to_datetime(recovered.index)
plot_df = pd.DataFrame(cases_by_date)


labels = ['deaths', 'recovered']
dfs = [deaths_by_date, recovered]
i=0
for label in labels:
    plot_df[label] = pd.DataFrame(dfs[i])
    i+=1
plot_df
```

	cases	deaths	recovered
date			
2020-01-21	1	0	NaN
2020-01-22	1	0	0.0
2020-01-23	1	0	0.0
2020-01-24	2	0	0.0
2020-01-25	3	0	0.0
...	...	...	...
2020-08-04	4778669	157299	1528979.0
2020-08-05	4832395	158552	1577851.0
2020-08-06	4889733	159623	1598624.0
2020-08-07	4950708	160977	1623870.0
2020-08-08	5005904	161942	1643118.0

201 rows × 3 columns

```
#plot.
fig, ax = plt.subplots(1, figsize = (16,8))

plt.plot(plot_df['cases'], label = 'cases', color = 'blue', linewidth = 2.5, marker = 'o
plt.plot(plot_df['recovered'], label = 'recovered', color = 'green', linewidth = 2.5, ma
plt.plot(plot_df['deaths'], label = 'deaths', color = 'red', linewidth = 2.5, marker = '


#labels
plt.xlabel('Date', fontsize = 14)
plt.ylabel('Cases', fontsize = 14)
plt.title('Covid-19 United States Cases - Confirmed, Deaths, Recovered', fontsize = 20)
plt.legend()

#formatting
ax.xaxis.set_major_locator(months)
ax.format_xdata = mdates.DateFormatter('%Y-%m-%d')
ax.format_ydata = lambda x: '$%1.2f' % x
ax.grid(True)
ax.patch.set_facecolor('grey') #chance background color if needed.
ax.patch.set_alpha(0.2)
```



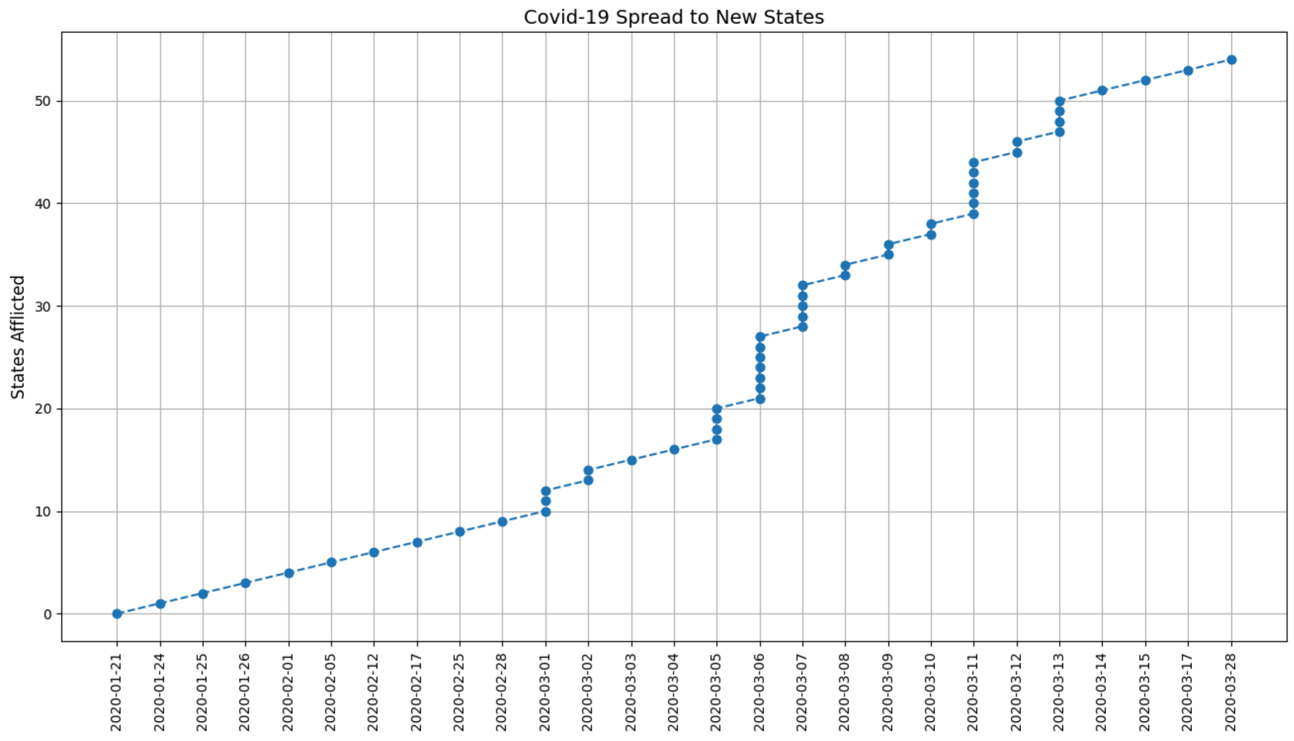
```
#states affected over time.
states_affected = []
cases_date = cases[['cases', 'date','state']]
for i, row in cases_date.iterrows():
    if row['cases'] != 0:
        states_affected.append(row)
states_affected = pd.DataFrame(states_affected)
```

```
#first 10 States to contract covid-19.
sorted_dates = states_affected.sort_values('date', ascending = True)
sorted_uniq_dates = sorted_dates.drop_duplicates('state')
sorted_uniq_dates.head(10)
```

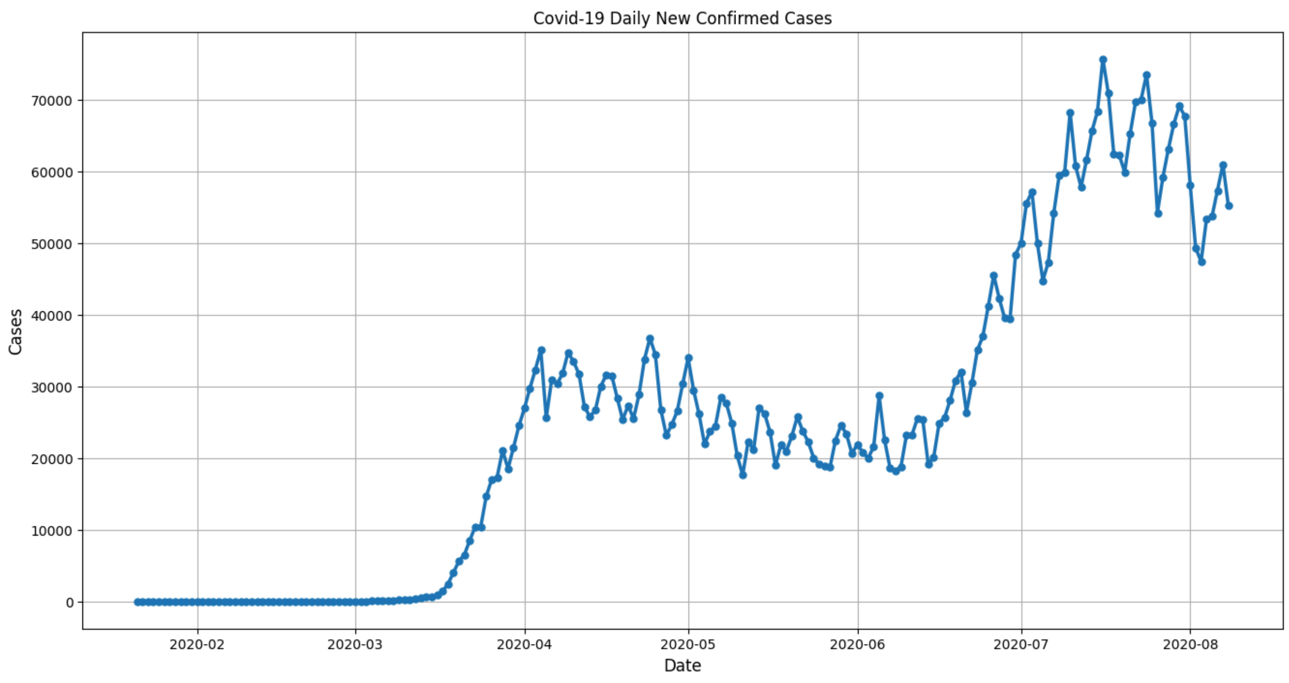
	cases	date	state
0	1	2020-01-21	Washington
3	1	2020-01-24	Illinois
5	1	2020-01-25	California
8	1	2020-01-26	Arizona
35	1	2020-02-01	Massachusetts
57	1	2020-02-05	Wisconsin
98	1	2020-02-12	Texas
133	10	2020-02-17	Nebraska
199	1	2020-02-25	Utah
225	1	2020-02-28	Oregon

```
#spread of Covid-19 to New States.
state_counts = []
for i in range(0, len(sorted_uniq_dates)):
    state_counts.append(i)

sorted_uniq_dates['count'] = state_counts

plt.figure(figsize = (16,8))
plt.scatter(x = sorted_uniq_dates['date'], y = sorted_uniq_dates['count'])
plt.plot(sorted_uniq_dates['date'], sorted_uniq_dates['count'], 'o--')
plt.xticks(rotation=90)
plt.title('Covid-19 Spread to New States', fontsize = 14)
plt.ylabel('States Afflicted', fontsize = 12)
plt.grid(True)
```

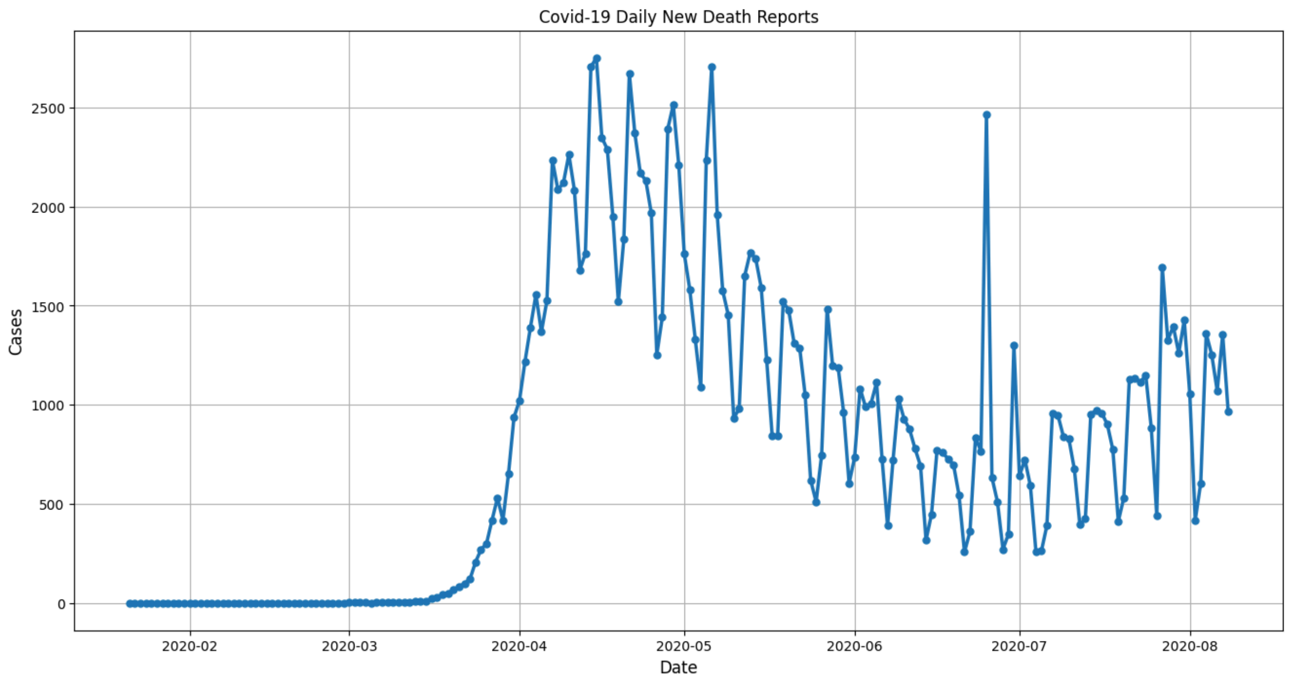
```
<ipython-input-48-7bd29661a3f2>:6: SettingWithCopyWarning:


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/u
```



```
cases_by_date.index = pd.to_datetime(cases_by_date.index)

#covid-19 daily new confirmed cases.
difference = cases_by_date.diff()
difference = difference.fillna(0)
fig, ax = plt.subplots(figsize = (16,8))

marker_style = dict(linewidth=2.5, linestyle = '-', marker = 'o', markersize = 5)
ax.plot(difference, **marker_style)

#labels
plt.xlabel('Date', fontsize = 12)
plt.ylabel('Cases', fontsize = 12)
plt.title('Covid-19 Daily New Confirmed Cases')

#formatting
ax.xaxis.set_major_locator(months)
ax.format_xdata = mdates.DateFormatter('%Y-%m-%d')
ax.format_ydata = lambda x: '$%1.2f' % x
ax.grid(True)
```



```
difference = deaths_by_date.diff()
difference = difference.fillna(0)
fig, ax = plt.subplots(figsize = (16,8))


marker_style = dict(linewidth=2.5, linestyle = '-', marker = 'o', markersize = 5)
ax.plot(difference, **marker_style)

#labels
plt.xlabel('Date', fontsize = 12)
plt.ylabel('Cases', fontsize = 12)
plt.title('Covid-19 Daily New Death Reports')

#formatting
ax.xaxis.set_major_locator(months)
ax.format_xdata = mdates.DateFormatter('%Y-%m-%d')
ax.format_ydata = lambda x: '$%1.2f' % x
ax.grid(True)
```



Double-click (or enter) to edit

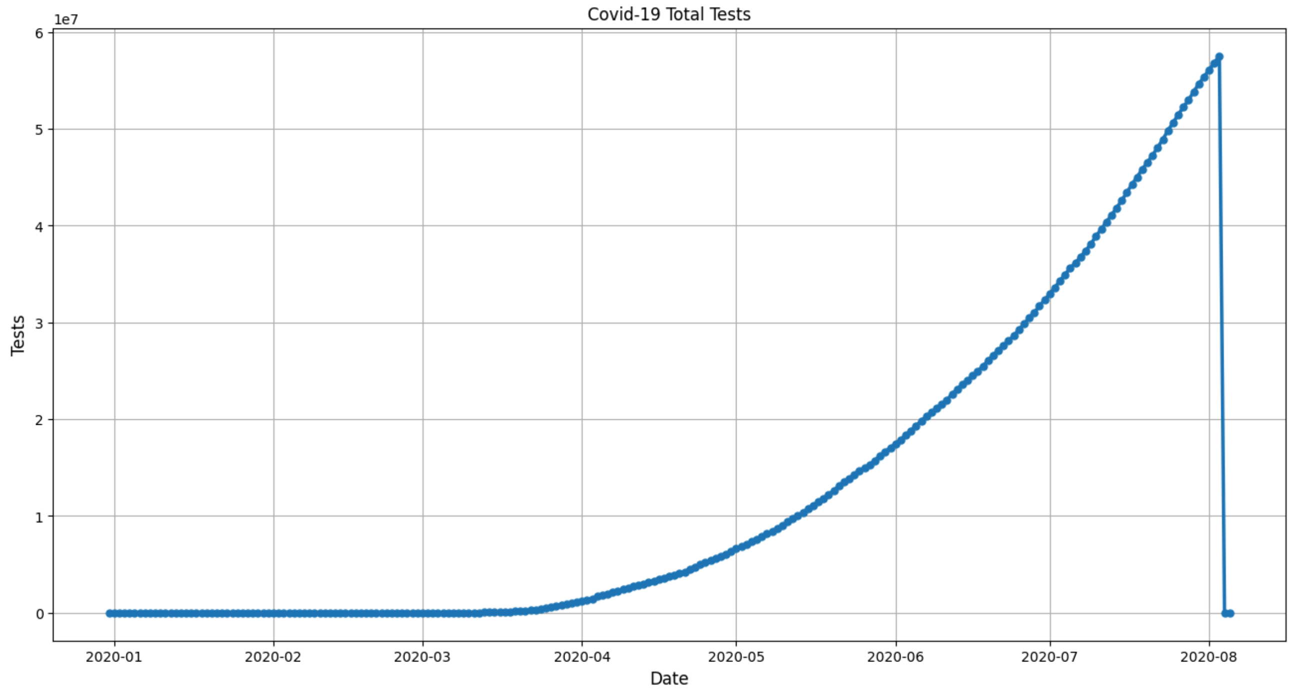
```
#prepare data.
data = data.merge(pop_data,
          how = 'left',
          left_on = 'state',
          right_on = 'state')


democratic = ['Washington', 'Oregon', 'Nevada', 'California', 'Colorado', 'New Mexico',
             'Maine', 'New York', 'New Hampshire', 'Vermont', 'Massachusetts', 'Rhode Is
             'Deleware', 'Maryland', 'Washington D.C.', 'Hawaii']

republican = ['Idaho', 'Montana', 'Utah', 'Arizona', 'Wyoming' ,'Texas', 'North Dakota',
             'Kansas', 'Oklahoma', 'Iowa', 'Missouri', 'Arkansas', 'Lousiana', 'Wisconsi
             'Tennessee', 'Alabama', 'Georgia', 'Florida', 'South Carolina', 'North Caro
             'Pennsylvania', 'Alaska']

#initialize empty column.
data['political status'] = np.nan

#create dummy variables.
for i, state in enumerate(data['state']):
    if state in democratic:
        data.at[i,'political status'] = 0
    else:
        data.at[i, 'political status'] = 1


#percents
democratic_cases = data[data['political status'] == 0]['cases'].sum()
republican_cases = data[data['political status'] == 1]['cases'].sum()

democratic_pop = data[data['political status'] == 0]['population'].sum()
republican_pop = data[data['political status'] == 1]['population'].sum()

democratic_case_percent = democratic_cases / democratic_pop * 100
republican_case_percent = republican_cases / republican_pop * 100

political_affiliation = pd.DataFrame({'Democratic': [democratic_case_percent],
                                     'Republican': [republican_case_percent]})
political_affiliation
```

	Democratic	Republican
0	0.600954	0.437555

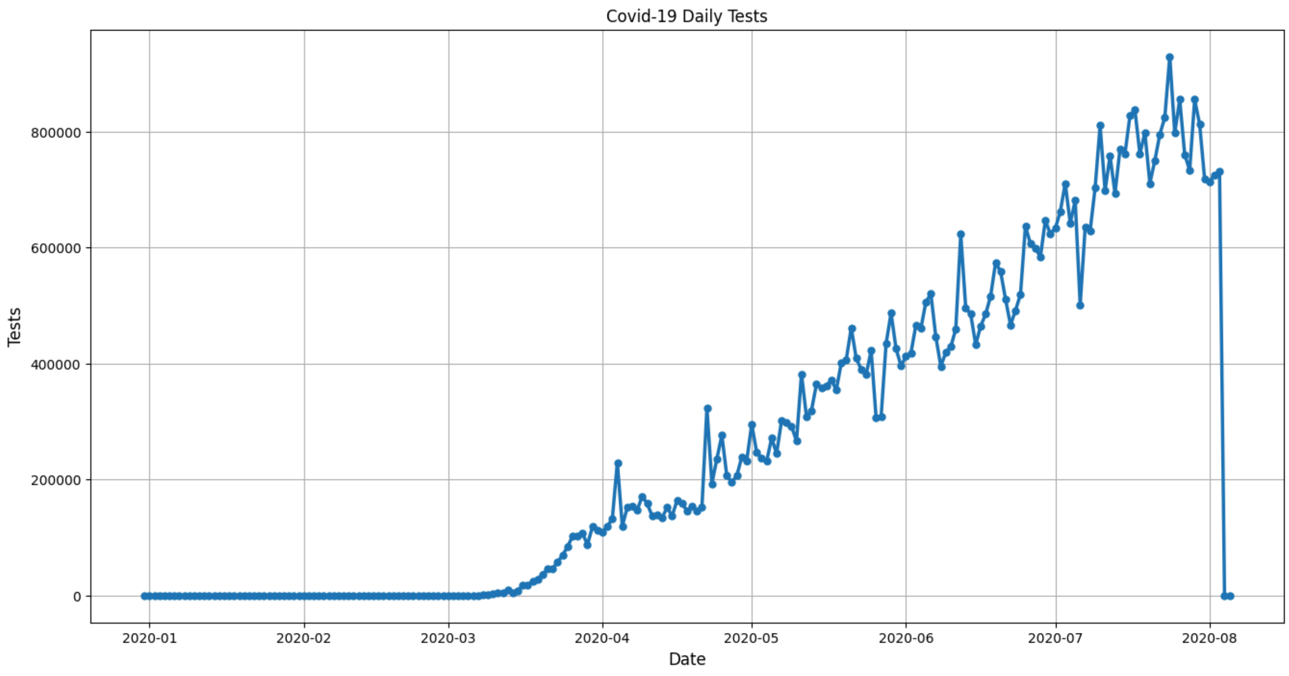
On average, a Democratic state will have 0.6% of the state population infected with Covid-19 while Republican states have slightly lower at 0.44%. Keep in mind that this statistic has a lot of variance and therefore no conclusions can be made, yet it is interesting to look at. I suggest that this variance is due to the disparity of urbanized vs ruralized areas.

Testing in the United States

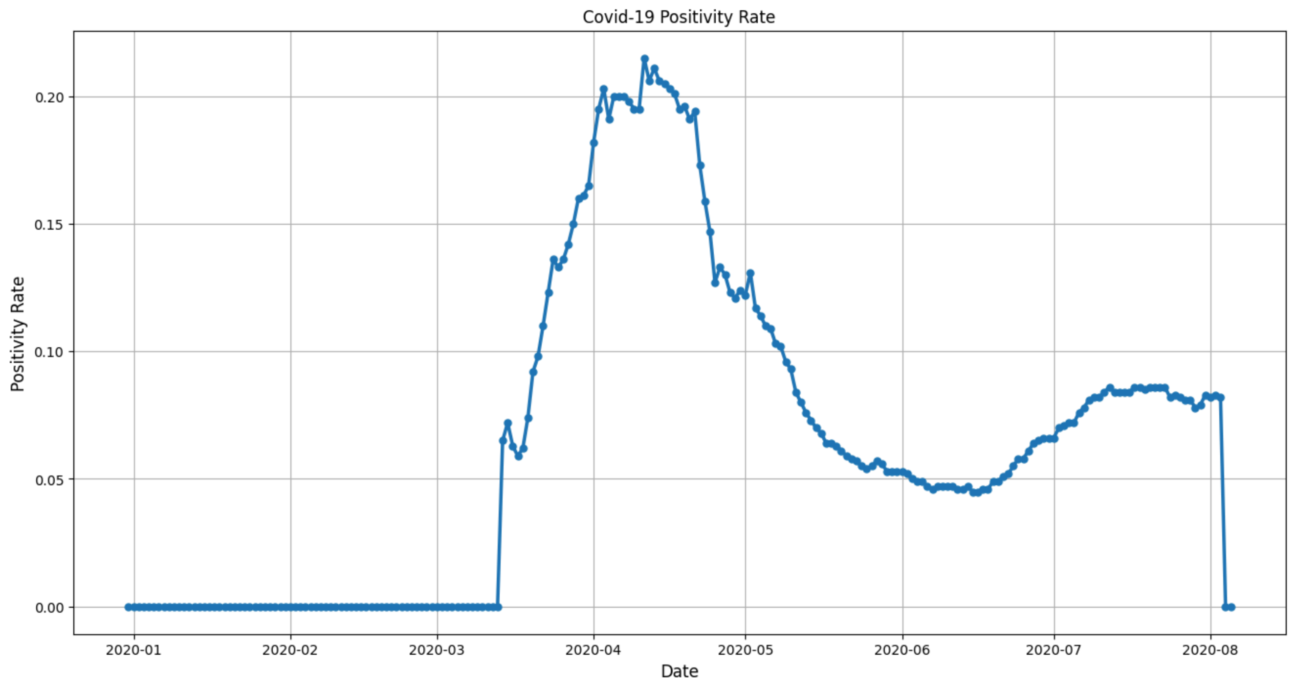
```
#coronavirus testing.
data_owid = pd.read_csv(r'data/owid-covid-data.csv')
united_states = data_owid['location'] == 'United States'
us_df = data_owid[united_states]
testing = us_df[['date', 'new_tests', 'total_tests', 'total_tests_per_thousand', 'new_te
testing = testing.fillna(0)


testing['date'] = pd.to_datetime(testing['date'])

fig, ax = plt.subplots(figsize = (16,8))


marker_style = dict(linewidth=2.5, linestyle = '-', marker = 'o', markersize = 5)
ax.plot(testing['date'], testing['total_tests'], **marker_style)

#Labels
plt.xlabel('Date', fontsize = 12)
plt.ylabel('Tests', fontsize = 12)
plt.title('Covid-19 Total Tests')

#Formatting
ax.xaxis.set_major_locator(months)
ax.format_xdata = mdates.DateFormatter('%Y-%m-%d')
ax.format_ydata = lambda x: '$%1.2f' % x
ax.grid(True)
```


Covid-19 Total Tests
1e7
6
5
4
3
2
1
0
Tests
2020-01
2020-02
2020-03
2020-04
2020-05
2020-06
2020-07
2020-08
Date

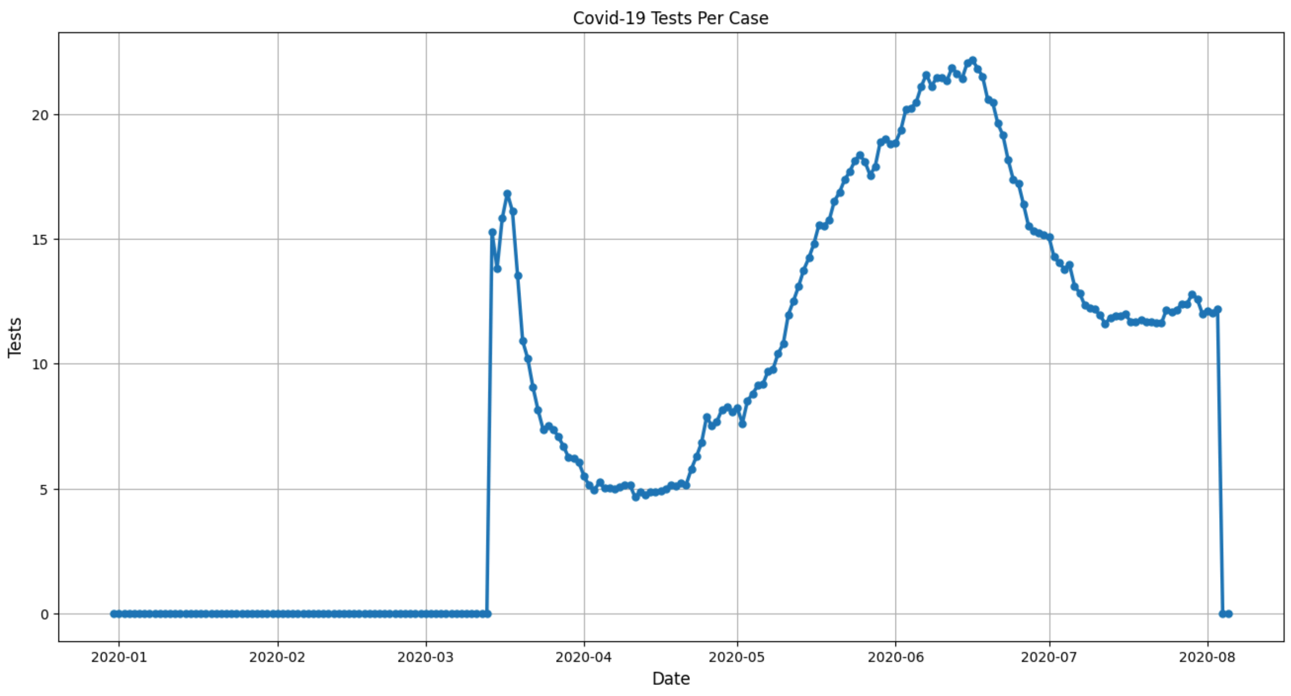
```
fig, ax = plt.subplots(figsize = (16,8))


marker_style = dict(linewidth=2.5, linestyle = '-', marker = 'o', markersize = 5)
ax.plot(testing['date'], testing['new_tests'], **marker_style)

#labels
plt.xlabel('Date', fontsize = 12)
plt.ylabel('Tests', fontsize = 12)
plt.title('Covid-19 Daily Tests')

#formatting
ax.xaxis.set_major_locator(months)
ax.format_xdata = mdates.DateFormatter('%Y-%m-%d')
ax.format_ydata = lambda x: '$%1.2f' % x
ax.grid(True)
```



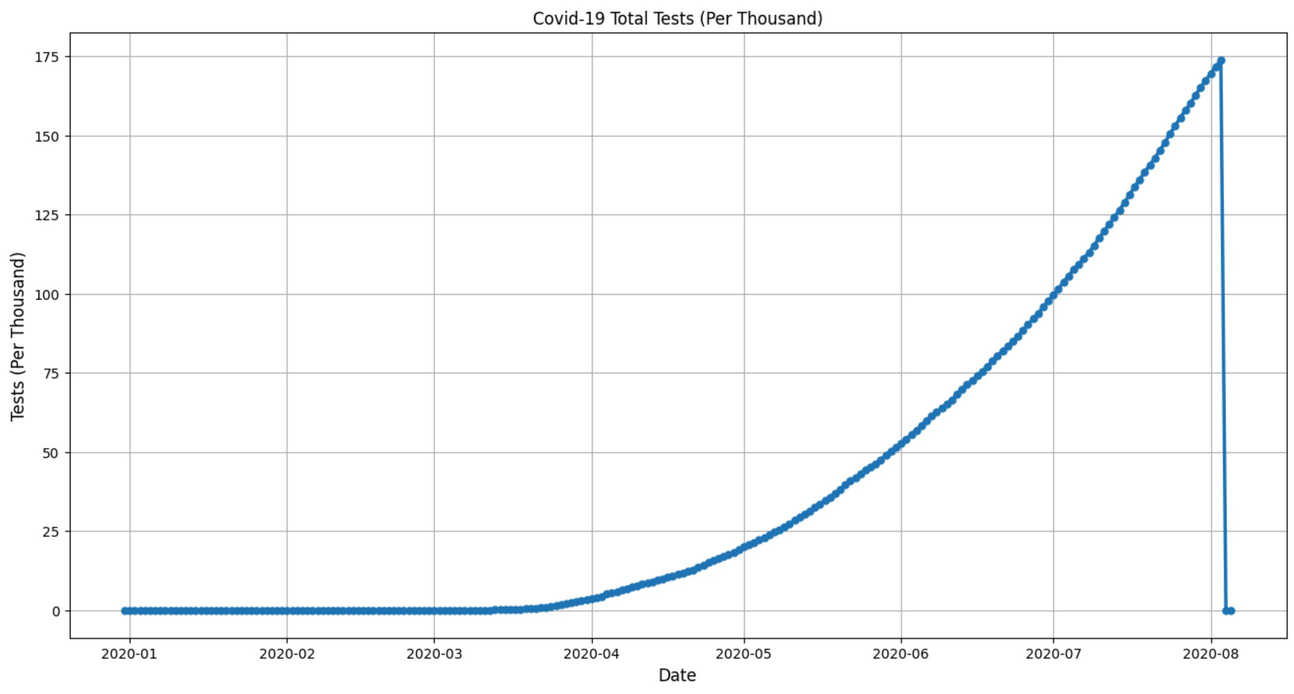
```
fig, ax = plt.subplots(figsize = (16,8))


marker_style = dict(linewidth=2.5, linestyle = '-', marker = 'o', markersize = 5)
ax.plot(testing['date'], testing['positive_rate'], **marker_style)

#labels
plt.xlabel('Date', fontsize = 12)
plt.ylabel('Positivity Rate', fontsize = 12)
plt.title('Covid-19 Positivity Rate')

#formatting
ax.xaxis.set_major_locator(months)
ax.format_xdata = mdates.DateFormatter('%Y-%m-%d')
ax.format_ydata = lambda x: '$%1.2f' % x
ax.grid(True)
```



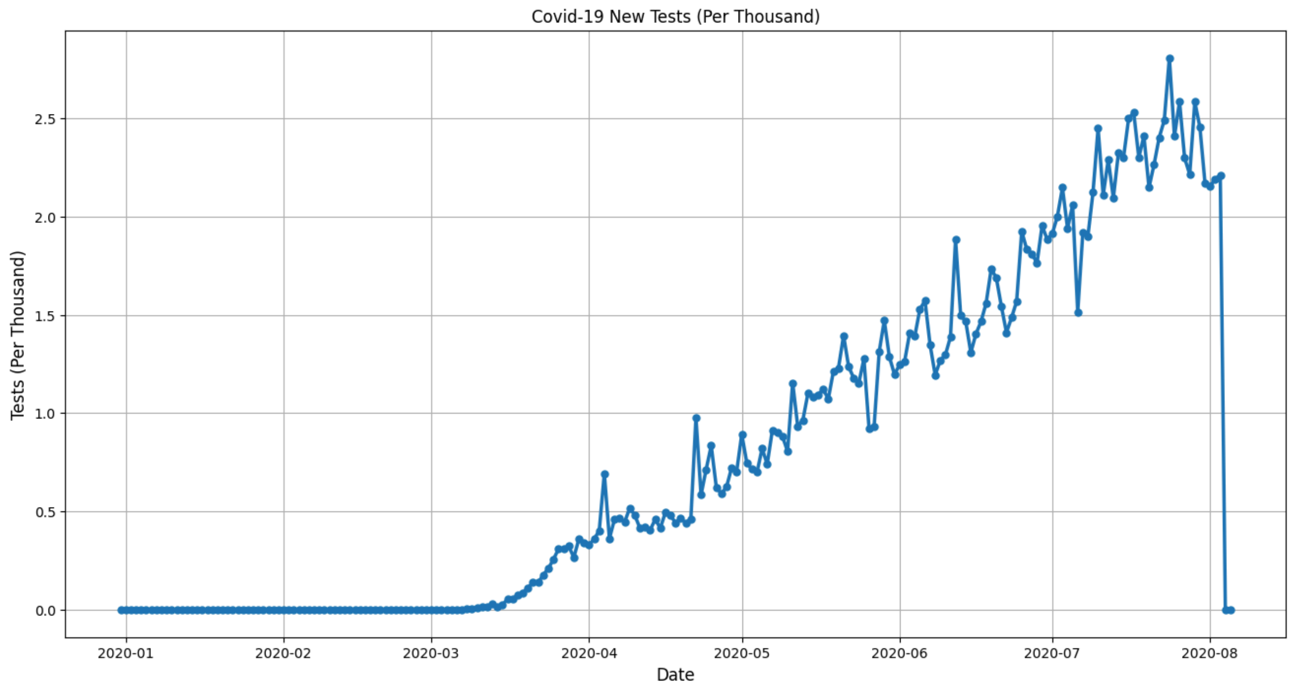
```
fig, ax = plt.subplots(figsize = (16,8))


marker_style = dict(linewidth=2.5, linestyle = '-', marker = 'o', markersize = 5)
ax.plot(testing['date'], testing['tests_per_case'], **marker_style)

#labels
plt.xlabel('Date', fontsize = 12)
plt.ylabel('Tests', fontsize = 12)
plt.title('Covid-19 Tests Per Case')

#formatting
ax.xaxis.set_major_locator(months)
ax.format_xdata = mdates.DateFormatter('%Y-%m-%d')
ax.format_ydata = lambda x: '$%1.2f' % x
ax.grid(True)
```



```
fig, ax = plt.subplots(figsize = (16,8))


marker_style = dict(linewidth=2.5, linestyle = '-', marker = 'o', markersize = 5)
ax.plot(testing['date'], testing['total_tests_per_thousand'], **marker_style)

#labels
plt.xlabel('Date', fontsize = 12)
plt.ylabel('Tests (Per Thousand)', fontsize = 12)
plt.title('Covid-19 Total Tests (Per Thousand)')

#formatting
ax.xaxis.set_major_locator(months)
ax.format_xdata = mdates.DateFormatter('%Y-%m-%d')
ax.format_ydata = lambda x: '$%1.2f' % x
ax.grid(True)
```



```
fig, ax = plt.subplots(figsize = (16,8))


marker_style = dict(linewidth=2.5, linestyle = '-', marker = 'o', markersize = 5)
ax.plot(testing['date'], testing['new_tests_per_thousand'], **marker_style)

#labels
plt.xlabel('Date', fontsize = 12)
plt.ylabel('Tests (Per Thousand)', fontsize = 12)
plt.title('Covid-19 New Tests (Per Thousand)')

#formatting
ax.xaxis.set_major_locator(months)
ax.format_xdata = mdates.DateFormatter('%Y-%m-%d')
ax.format_ydata = lambda x: '$%1.2f' % x
ax.grid(True)
```



Predictive Modeling

Prophet

We will be using the open source software Prophet to forecast future Covid-19 cases. It provides reliable predictions as it is robust to shifts in the data and handles outliers. Our model for forecasting confirmed cases, deaths and recovered patients will be relatively straightforward as the data follows a polynomial trend.

Cases

```
confirmed = pd.DataFrame(cases_by_date)
```

```
confirmed.tail()
```

	cases
date	
2020-08-04	4778669
2020-08-05	4832395
2020-08-06	4889733
2020-08-07	4950708
2020-08-08	5005904

```
#clean dataframe for usability with prophet.
confirmed.reset_index(level=0, inplace=True)
confirmed.columns = ['ds', 'y']
```

```
#setting up the model to predict 10 days ahead.
model = Prophet(interval_width = 0.95)
model.fit(confirmed)
future = model.make_future_dataframe(periods=10)
```

```
INFO:prophet:Disabling yearly seasonality. Run prophet with yearly_seasonality=True
INFO:prophet:Disabling daily seasonality. Run prophet with daily_seasonality=True to
DEBUG:cmdstanpy:input tempfile: /tmp/tmpz2b1mshk/nuqe_qo7.json
DEBUG:cmdstanpy:input tempfile: /tmp/tmpz2b1mshk/a__a2vik.json
DEBUG:cmdstanpy:idx 0
DEBUG:cmdstanpy:running CmdStan, num_threads: None
DEBUG:cmdstanpy:CmdStan args: ['/usr/local/lib/python3.10/dist-packages/prophet/stan
16:50:49 - cmdstanpy - INFO - Chain [1] start processing
```

```
INFO:cmdstanpy:Chain [1] start processing
16:50:49 - cmdstanpy - INFO - Chain [1] done processing
INFO:cmdstanpy:Chain [1] done processing
```

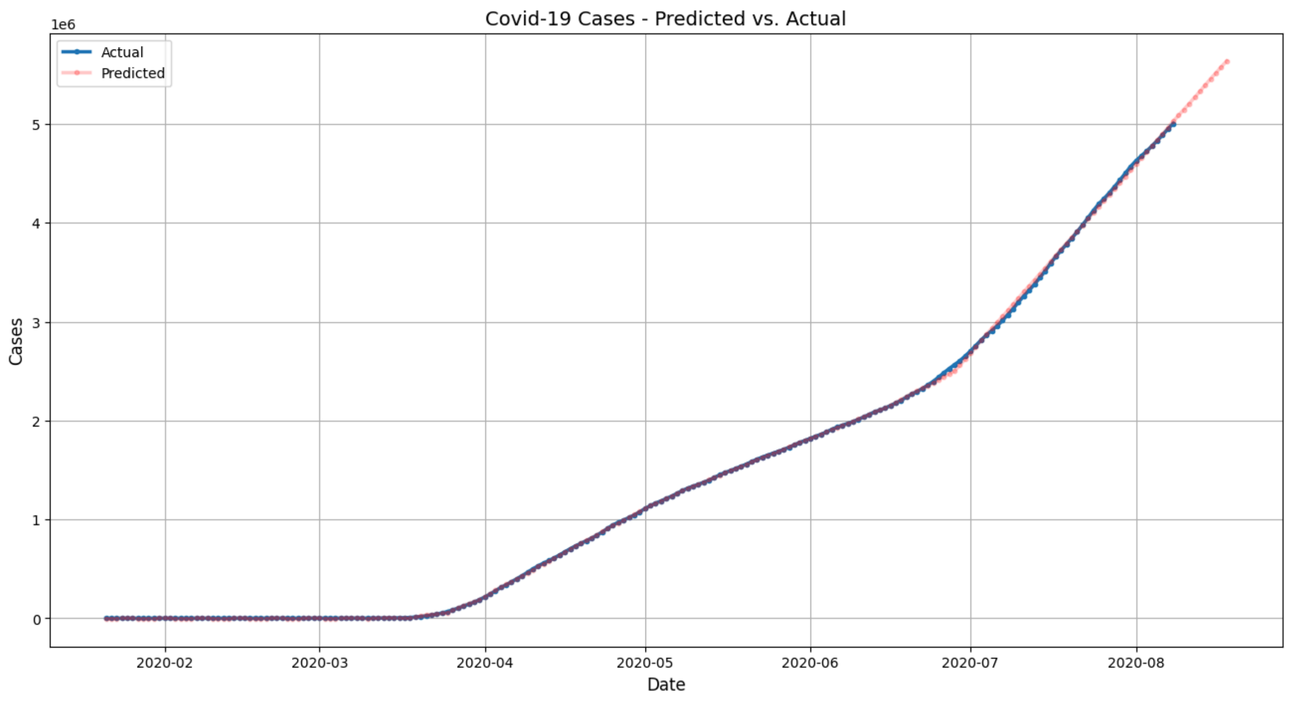
```
#predicting future forecast with date.
forecast = model.predict(future)
forecast[['ds', 'yhat', 'yhat_lower', 'yhat_upper']].tail(10)
```

	ds	yhat	yhat_lower	yhat_upper
201	2020-08-09	5.088108e+06	5.061117e+06	5.117030e+06
202	2020-08-10	5.146887e+06	5.117816e+06	5.175719e+06
203	2020-08-11	5.207428e+06	5.178792e+06	5.235583e+06
204	2020-08-12	5.269116e+06	5.239025e+06	5.299303e+06
205	2020-08-13	5.332284e+06	5.297451e+06	5.366769e+06
206	2020-08-14	5.396716e+06	5.355504e+06	5.431851e+06
207	2020-08-15	5.458971e+06	5.411420e+06	5.504089e+06
208	2020-08-16	5.519159e+06	5.461193e+06	5.574885e+06
209	2020-08-17	5.577939e+06	5.514568e+06	5.636015e+06
210	2020-08-18	5.638479e+06	5.565339e+06	5.705972e+06

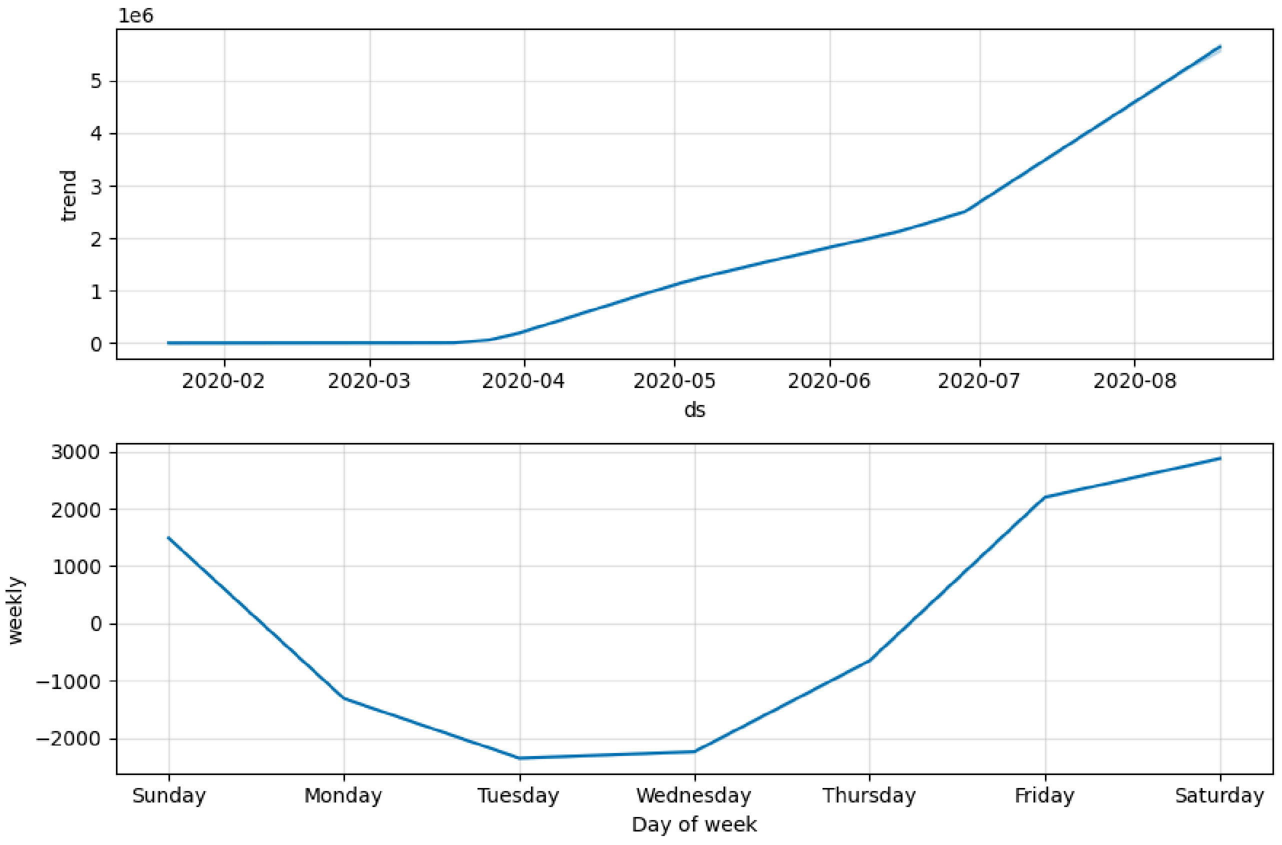
In the table above, yhat signifies the predicted value while both lower and upper columns refer to the bounds. This is treated as a 95% confidence interval and thus there is 95% certainty that the given value will be between these upper and lower bounds.

```
pred_cases = forecast[['ds', 'yhat']]
#pred_cases['ds'] = pd.to_datetime(pred_cases['ds'])
pred_cases.set_index('ds', inplace=True)
```

```
#Prediction plot (cases) + 10 days.

fig, ax = plt.subplots(figsize = (16,8))
marker_style = dict(linewidth=2.5, marker = 'o', markersize = 3)
ax.plot(cases_by_date, **marker_style, linestyle = '-', label = 'Actual')
ax.plot(pred_cases, **marker_style, linestyle = '-', label = 'Predicted', color = 'r', a
plt.ylabel("Cases", fontsize = 12)
plt.xlabel('Date', fontsize = 12)
plt.title('Covid-19 Cases - Predicted vs. Actual', fontsize = 14)
ax.legend(loc='upper left')

#ax.patch.set_facecolor('grey')
#ax.patch.set_alpha(0.2)

#Format ticks
ax.xaxis.set_major_locator(months)
ax.grid(True)

plt.show()
```



```
conf_comp_plot = model.plot_components(forecast)
```



```
deaths = pd.DataFrame(deaths_by_date)
deaths.reset_index(level=0, inplace=True)
deaths.columns = ['ds', 'y']
```

```
model = Prophet(interval_width = 0.95)
model.fit(deaths)
future = model.make_future_dataframe(periods=10)
```

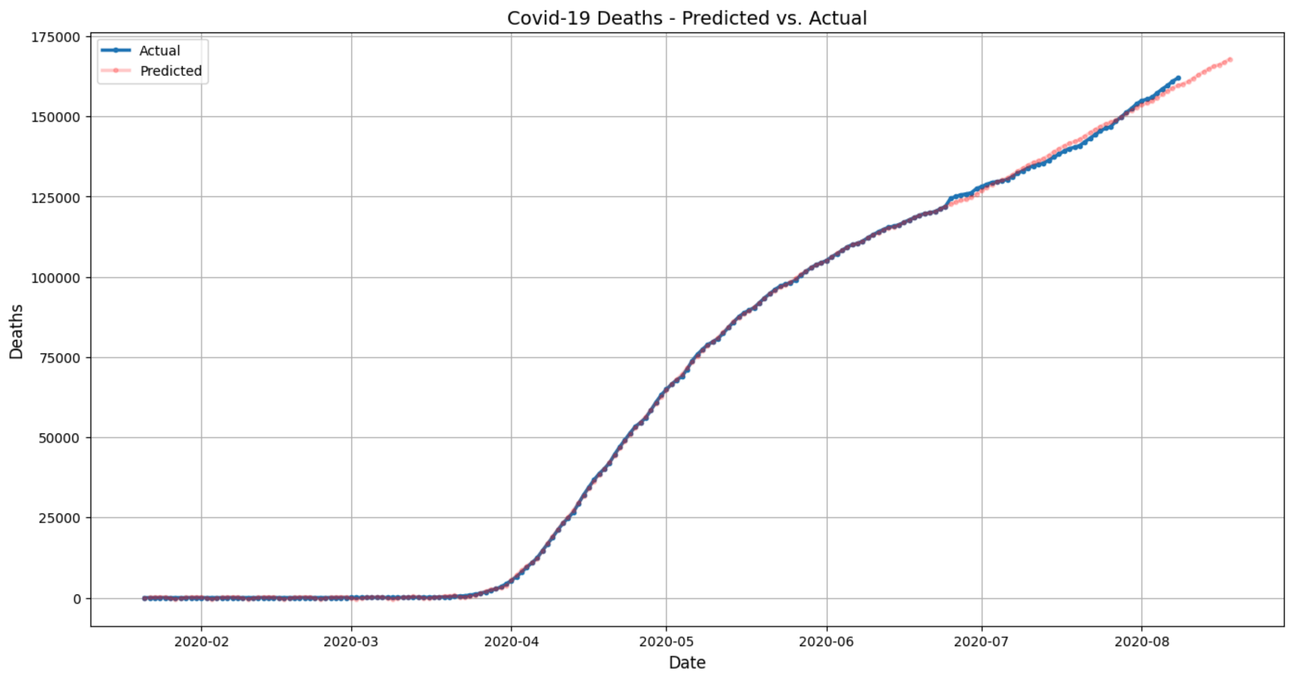
```
INFO:prophet:Disabling yearly seasonality. Run prophet with yearly_seasonality=True
INFO:prophet:Disabling daily seasonality. Run prophet with daily_seasonality=True to
DEBUG:cmdstanpy:input tempfile: /tmp/tmpz2b1mshk/0ov6160p.json
DEBUG:cmdstanpy:input tempfile: /tmp/tmpz2b1mshk/xffth0_t.json
DEBUG:cmdstanpy:idx 0
DEBUG:cmdstanpy:running CmdStan, num_threads: None
DEBUG:cmdstanpy:CmdStan args: ['/usr/local/lib/python3.10/dist-packages/prophet/stan_
16:51:10 - cmdstanpy - INFO - Chain [1] start processing
```

```
INFO:cmdstanpy:Chain [1] start processing
16:51:10 - cmdstanpy - INFO - Chain [1] done processing
INFO:cmdstanpy:Chain [1] done processing
```

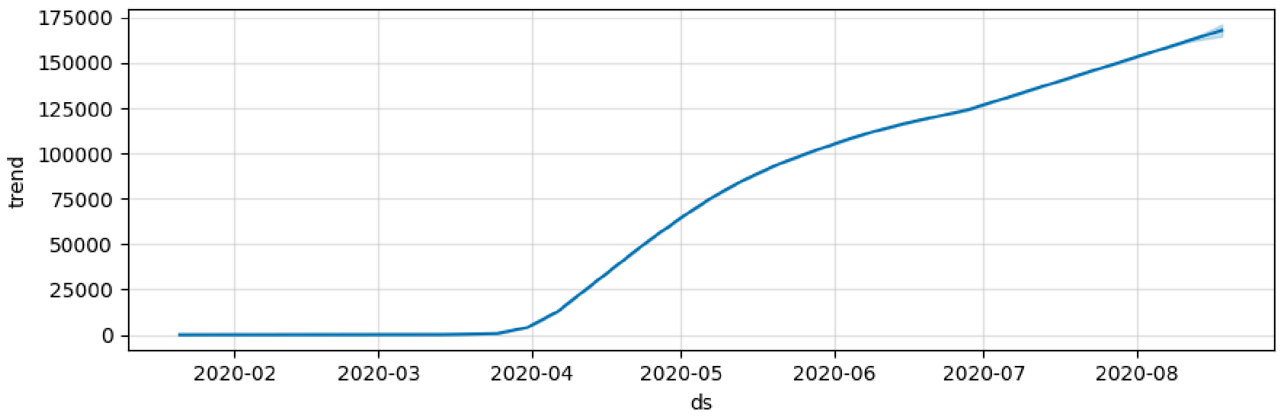
```
forecast = model.predict(future)
forecast[['ds', 'yhat', 'yhat_lower', 'yhat_upper']].tail(10)
```

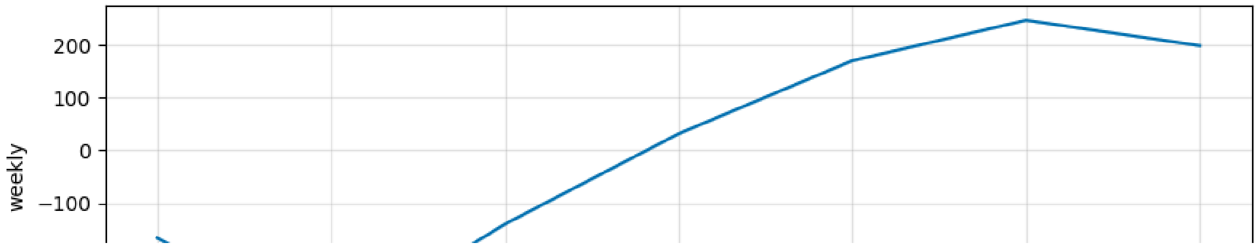
	ds	yhat	yhat_lower	yhat_upper
201	2020-08-09	160132.268899	158783.433064	161458.997456
202	2020-08-10	160814.175051	159424.483294	162198.060398
203	2020-08-11	161873.989281	160451.789944	163268.736604
204	2020-08-12	162903.248612	161401.656119	164466.880551
205	2020-08-13	163899.589575	162172.000005	165474.405440
206	2020-08-14	164833.978538	162745.656569	166780.646317
207	2020-08-15	165643.521681	163600.367353	167731.756095
208	2020-08-16	166136.567446	163660.353142	168823.062805
209	2020-08-17	166818.473598	164231.489450	169796.222652
210	2020-08-18	167878.287829	164469.572456	171362.723467

```
pred_deaths = forecast[['ds', 'yhat']]
#pred_cases['ds'] = pd.to_datetime(pred_cases['ds'])
pred_deaths.set_index('ds', inplace=True)


#Prediction plot (deaths) + 10 days.

fig, ax = plt.subplots(figsize = (16,8))
marker_style = dict(linewidth=2.5, marker = 'o', markersize = 3)
ax.plot(deaths_by_date, **marker_style, linestyle = '-', label = 'Actual')
ax.plot(pred_deaths, **marker_style, linestyle = '-', label = 'Predicted', color = 'r', 
plt.ylabel("Deaths", fontsize = 12)
plt.xlabel('Date', fontsize = 12)
plt.title('Covid-19 Deaths - Predicted vs. Actual', fontsize = 14)
ax.legend(loc='upper left')

#ax.patch.set_facecolor('grey')
#ax.patch.set_alpha(0.2)

#Format ticks
ax.xaxis.set_major_locator(months)
ax.grid(True)

plt.show()
```



```
deaths_comp_plot = model.plot_components(forecast)
```





```
recovered = pd.DataFrame(recovered)
recovered.reset_index(level=0, inplace=True)
recovered.columns = ['ds', 'y']
```

Day of week

```
model = Prophet(interval_width = 0.95)
model.fit(recovered)
future = model.make_future_dataframe(periods=10)
```

```
INFO:prophet:Disabling yearly seasonality. Run prophet with yearly_seasonality=True
INFO:prophet:Disabling daily seasonality. Run prophet with daily_seasonality=True to
DEBUG:cmdstanpy:input tempfile: /tmp/tmpz2b1mshk/ygvhp0qw.json
DEBUG:cmdstanpy:input tempfile: /tmp/tmpz2b1mshk/6jtvno3i.json
DEBUG:cmdstanpy:idx 0
DEBUG:cmdstanpy:running CmdStan, num_threads: None
DEBUG:cmdstanpy:CmdStan args: ['/usr/local/lib/python3.10/dist-packages/prophet/stan_
16:51:31 - cmdstanpy - INFO - Chain [1] start processing
INFO:cmdstanpy:Chain [1] start processing
16:51:31 - cmdstanpy - INFO - Chain [1] done processing
INFO:cmdstanpy:Chain [1] done processing
```

```
forecast = model.predict(future)
forecast[['ds', 'yhat', 'yhat_lower', 'yhat_upper']].tail(10)
```