Elements Of Data Science - F2023

Week 12: Time Series

12/11/2023

TODOs

- Readings:
    - Recommended: DSFS: Chap 9: Getting Data
    - Recommended: DSFS: Chap 23: Databases and SQL
- HW4, **Due December 15 11:59pm ET**
- Final
    - Review sheet in github repo (soon!)
    - In class, in person.

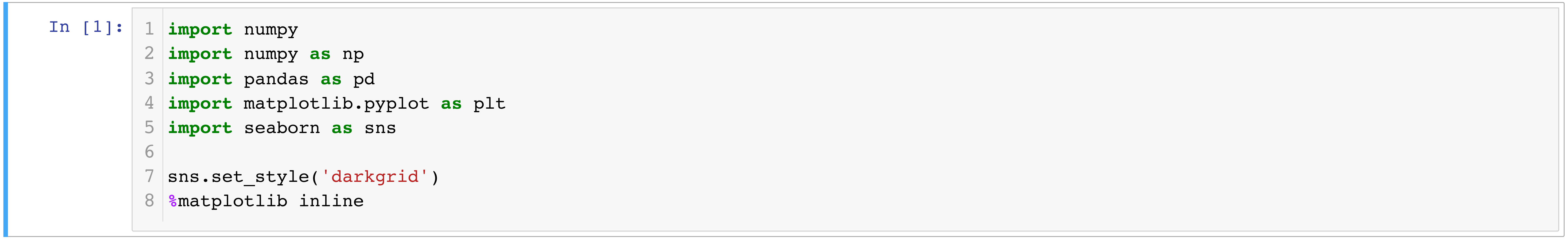
Today

- Time Series Transformations

Questions?

Environment Setup

Environment Setup



```python
import numpy
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import seaborn as sns

sns.set_style('darkgrid')
%matplotlib inline
```

Time Series

- Data ordered in time

- Applications
    - Financial
    - Economic
    - Scientific
    - etc.

Time Series Differences

- **Non-i.i.d.** : not independent and identically distributed

- not independent
    - Ex: Stock price

- not-identically distributed
    - Ex: Seasonality

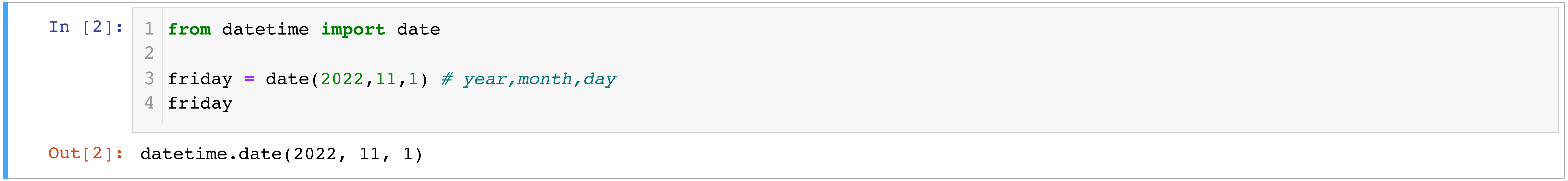
- In other words: Order matters!

Representing Time in Python

- `datetime` library
- Pandas `Timestamp`

`datetime.date`

datetime.date



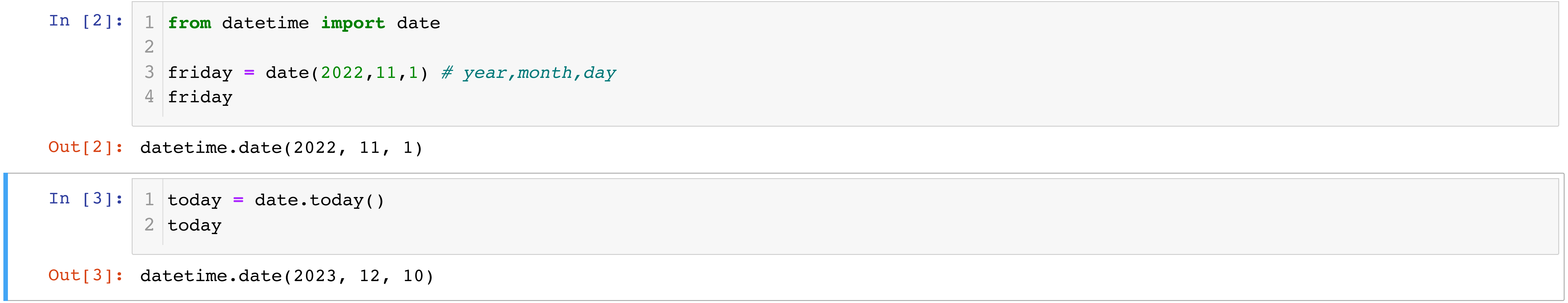
In [2]:

```python
from datetime import date

friday = date(2022,11,1) # year,month,day
friday
```

Out[2]:

```
datetime.date(2022, 11, 1)
```

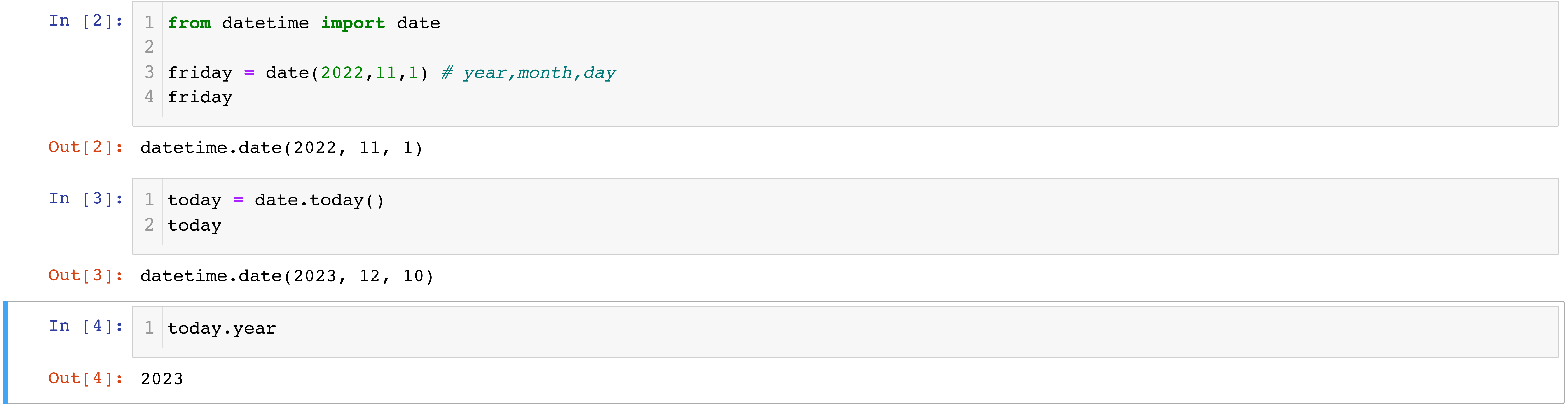
datetime.date



```
In [2]:
from datetime import date

friday = date(2022,11,1) # year,month,day
friday

Out[2]: datetime.date(2022, 11, 1)
```

```
In [3]:
today = date.today()
today

Out[3]: datetime.date(2023, 12, 10)
```

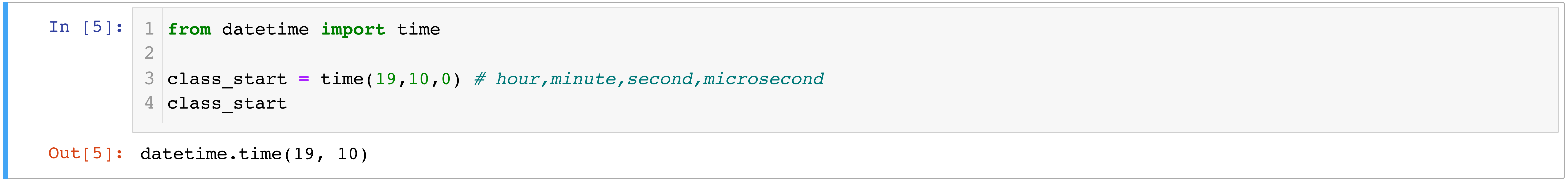
datetime.date



```
In [2]: from datetime import date

        friday = date(2022,11,1) # year,month,day
        friday

Out[2]: datetime.date(2022, 11, 1)

In [3]: today = date.today()
        today

Out[3]: datetime.date(2023, 12, 10)

In [4]: today.year

Out[4]: 2023
```

`datetime.time`

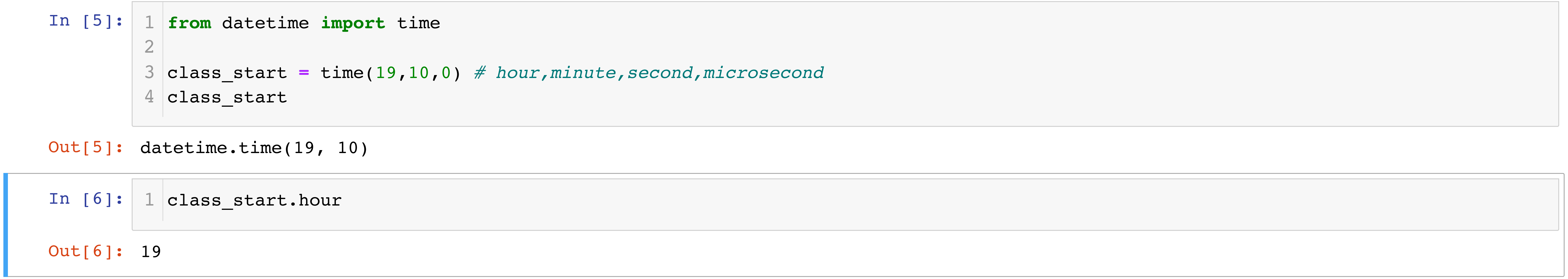
datetime.time



```
In [5]:
from datetime import time

class_start = time(19,10,0) # hour,minute,second,microsecond
class_start
```

```
Out[5]: datetime.time(19, 10)
```

datetime.time



```
In [5]:
from datetime import time

class_start = time(19,10,0) # hour,minute,second,microsecond
class_start
```

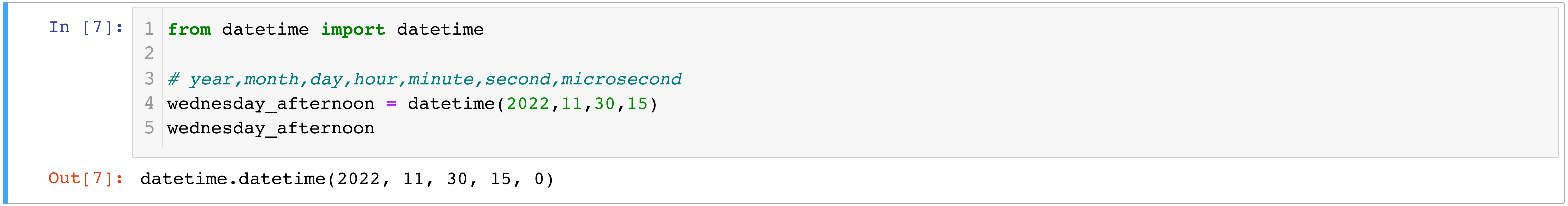
```
Out[5]: datetime.time(19, 10)
```

```
In [6]:
class_start.hour
```

```
Out[6]: 19
```

`datetime.datetime`

datetime.datetime

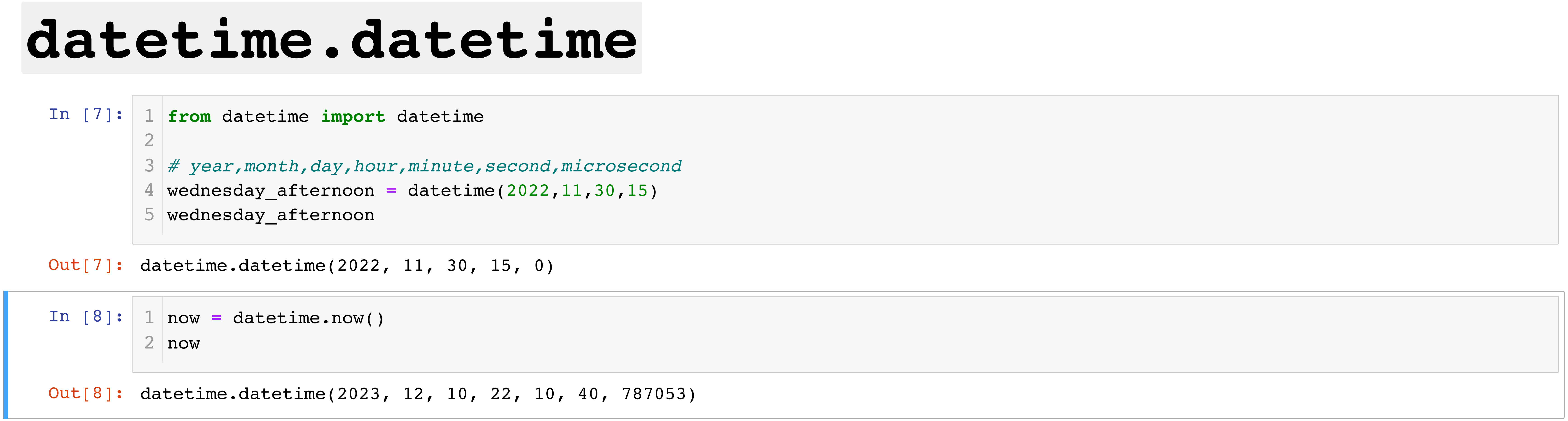


In [7]:

```
from datetime import datetime

# year,month,day,hour,minute,second,microsecond
wednesday_afternoon = datetime(2022,11,30,15)
wednesday_afternoon
```

Out[7]:

```
datetime.datetime(2022, 11, 30, 15, 0)
```



datetime.datetime

In [7]:

```python
from datetime import datetime

# year,month,day,hour,minute,second,microsecond
wednesday_afternoon = datetime(2022,11,30,15)
wednesday_afternoon
```

Out[7]:

```
datetime.datetime(2022, 11, 30, 15, 0)
```

In [8]:

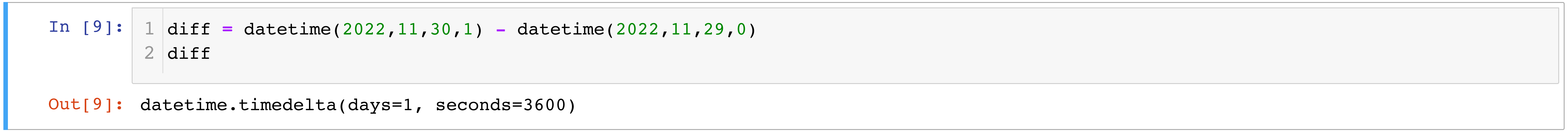
```python
now = datetime.now()
now
```

Out[8]:

```
datetime.datetime(2023, 12, 10, 22, 10, 40, 787053)
```

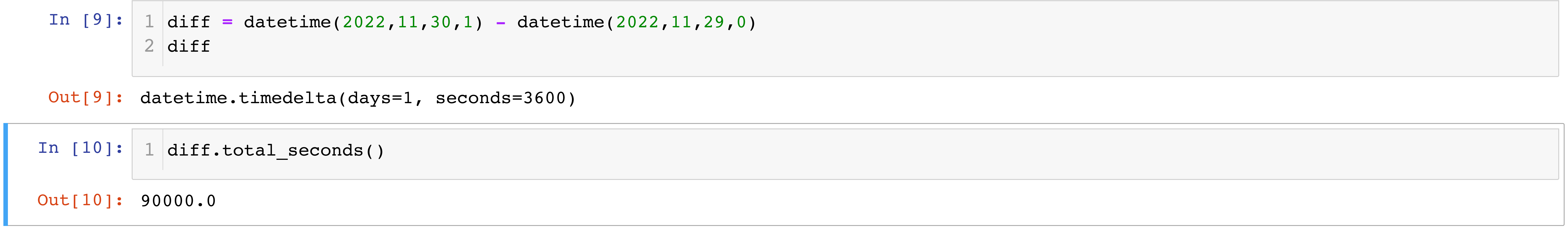
`datetime.timedelta`

datetime.timedelta



```
In [9]:  diff = datetime(2022,11,30,1) - datetime(2022,11,29,0)
         diff

Out[9]: datetime.timedelta(days=1, seconds=3600)
```

datetime.timedelta



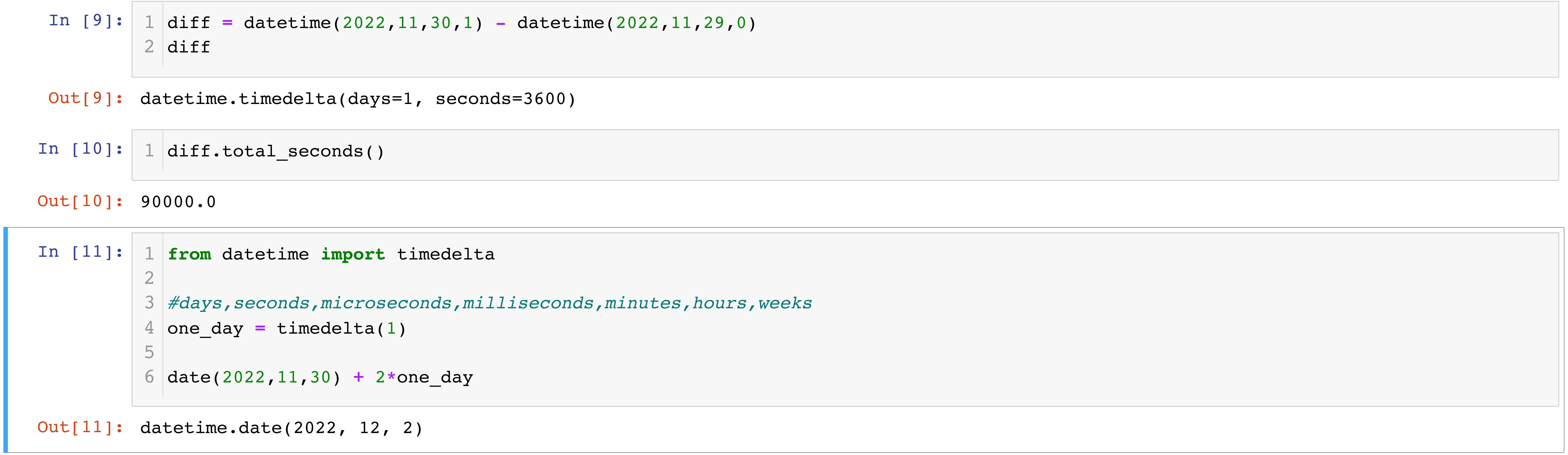
In [9]:
```
diff = datetime(2022,11,30,1) - datetime(2022,11,29,0)
diff
```

Out[9]:
```
datetime.timedelta(days=1, seconds=3600)
```

In [10]:
```
diff.total_seconds()
```

Out[10]:
```
90000.0
```

datetime.timedelta



```
In [9]:  diff = datetime(2022,11,30,1) - datetime(2022,11,29,0)
         diff

Out[9]:  datetime.timedelta(days=1, seconds=3600)
```

```
In [10]:  diff.total_seconds()

Out[10]:  90000.0
```

```
In [11]:  from datetime import timedelta

          #days,seconds,microseconds,milliseconds,minutes,hours,weeks
          one_day = timedelta(1)

          date(2022,11,30) + 2*one_day

Out[11]:  datetime.date(2022, 12, 2)
```

Printing Datetimes: `strftime()`

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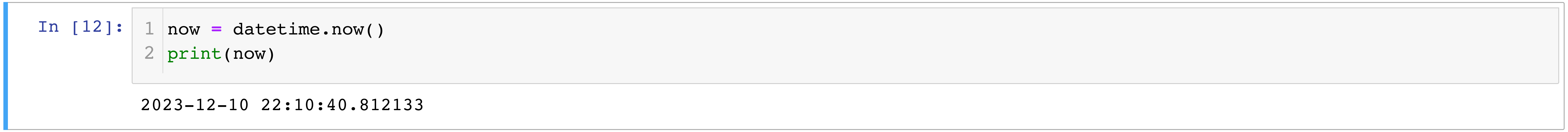
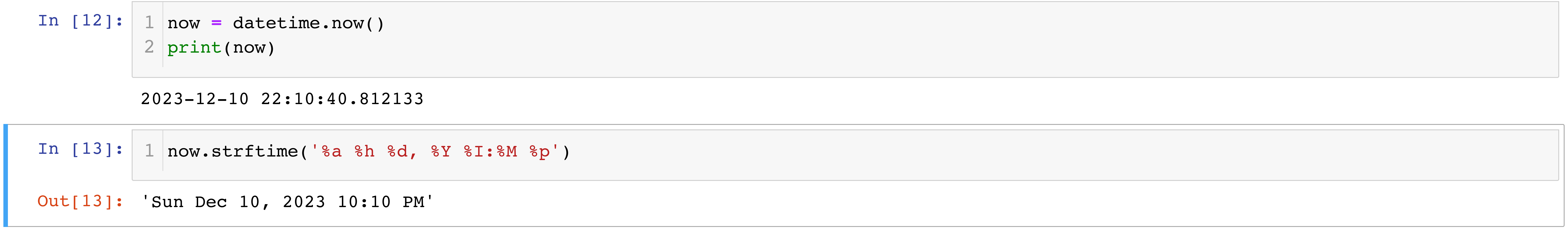


In [12]:

```python
now = datetime.now()
print(now)
```

```
2023-12-10 22:10:40.812133
```

Printing Datetimes: `strftime()`



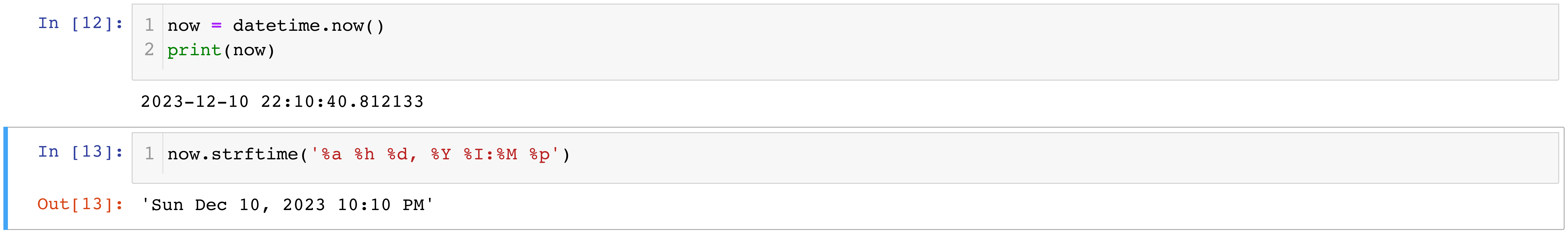
```
In [12]: now = datetime.now()
         print(now)

2023-12-10 22:10:40.812133
```

```
In [13]: now.strftime('%a %h %d, %Y %I:%M %p')

Out[13]: 'Sun Dec 10, 2023 10:10 PM'
```

Printing Datetimes: `strftime()`



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2023-12-10 22:10:40.812133
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now.strftime('%a %h %d, %Y %I:%M %p')
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Out[13]:
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'Sun Dec 10, 2023 10:10 PM'
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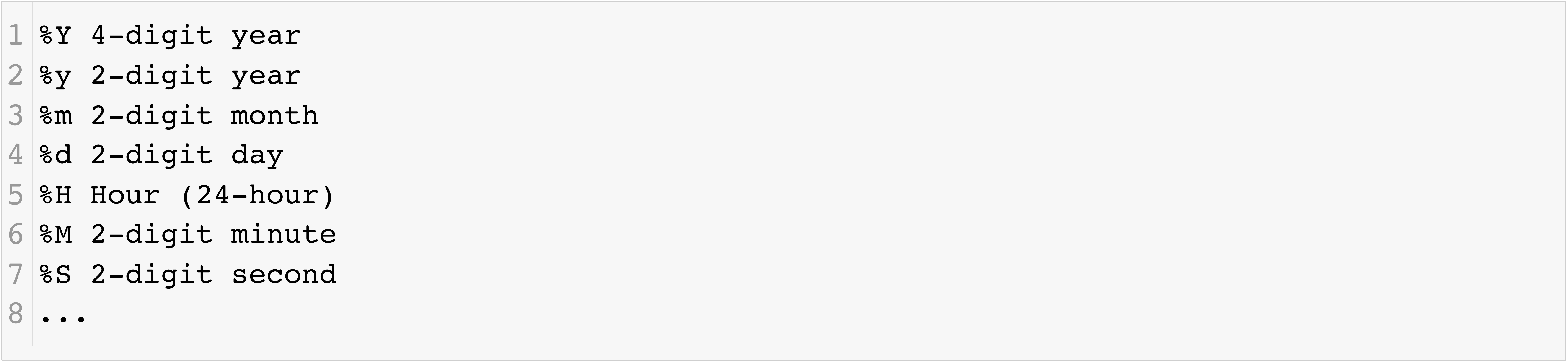
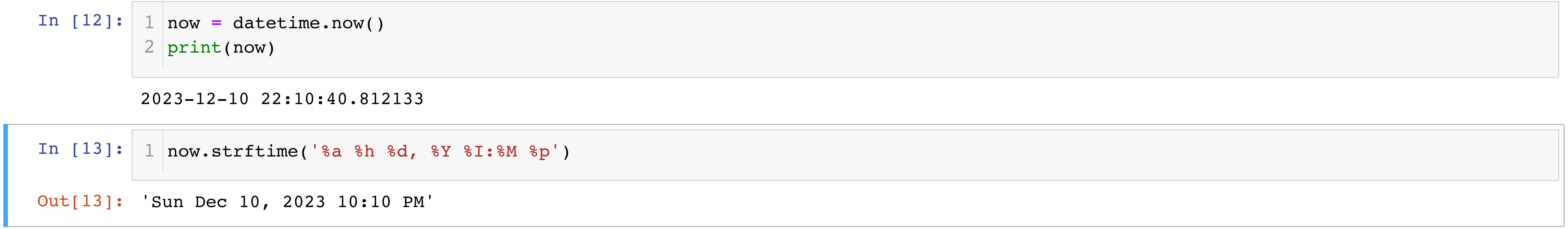


```
%Y 4-digit year
%y 2-digit year
%m 2-digit month
%d 2-digit day
%H Hour (24-hour)
%M 2-digit minute
%S 2-digit second
...
```

Printing Datetimes: `strftime()`



In [12]:
```python
now = datetime.now()
print(now)
```

```
2023-12-10 22:10:40.812133
```

In [13]:
```python
now.strftime('%a %h %d, %Y %I:%M %p')
```

Out[13]:
```
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```

```
%Y 4-digit year
%y 2-digit year
%m 2-digit month
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%H Hour (24-hour)
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```

See strftime.org and strfti.me

Parsing Datetimes: `pandas.to_datetime()`

- `dateutil.parser` available
- pandas has parser built in: `pd.to_datetime()`

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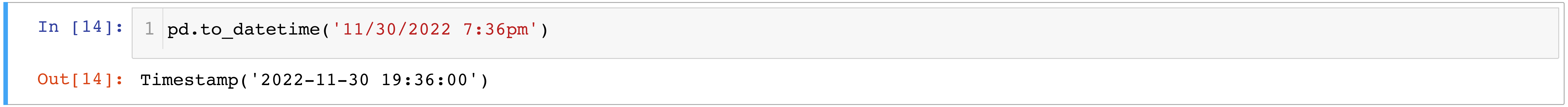
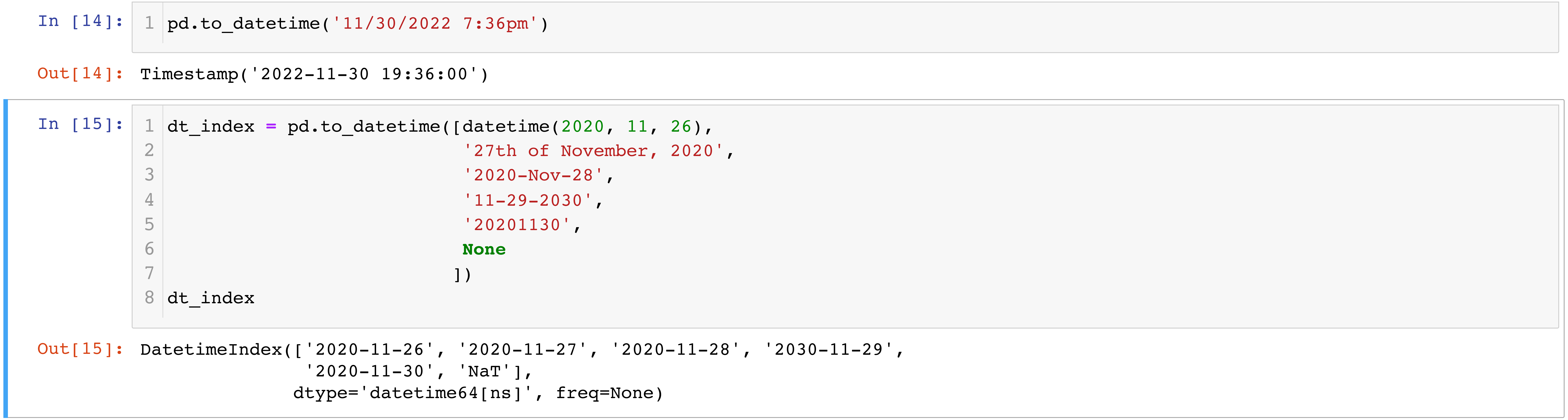


```
In [14]: pd.to_datetime('11/30/2022 7:36pm')

Out[14]: Timestamp('2022-11-30 19:36:00')
```

Parsing Datetimes: `pandas.to_datetime()`

- `dateutil.parser` available
- pandas has parser built in: `pd.to_datetime()`



```
In [14]: pd.to_datetime('11/30/2022 7:36pm')

Out[14]: Timestamp('2022-11-30 19:36:00')
```

```
In [15]: dt_index = pd.to_datetime([datetime(2020, 11, 26),
                                    '27th of November, 2020',
                                    '2020-Nov-28',
                                    '11-29-2030',
                                    '20201130',
                                    None
                                   ])
         dt_index

Out[15]: DatetimeIndex(['2020-11-26', '2020-11-27', '2020-11-28', '2030-11-29',
                        '2020-11-30', 'NaT'],
                       dtype='datetime64[ns]', freq=None)
```

`pandas.Timestamp`

- like `datetime.datetime`
- can include **timezone** and **frequency** info
- can handle a missing time: `NaT`
- can be used anywhere `datetime` can be used
- an array of Timestamps can be used as an index

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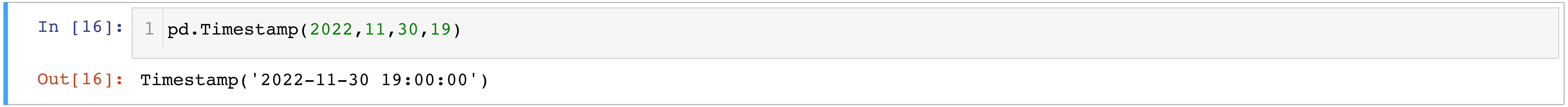
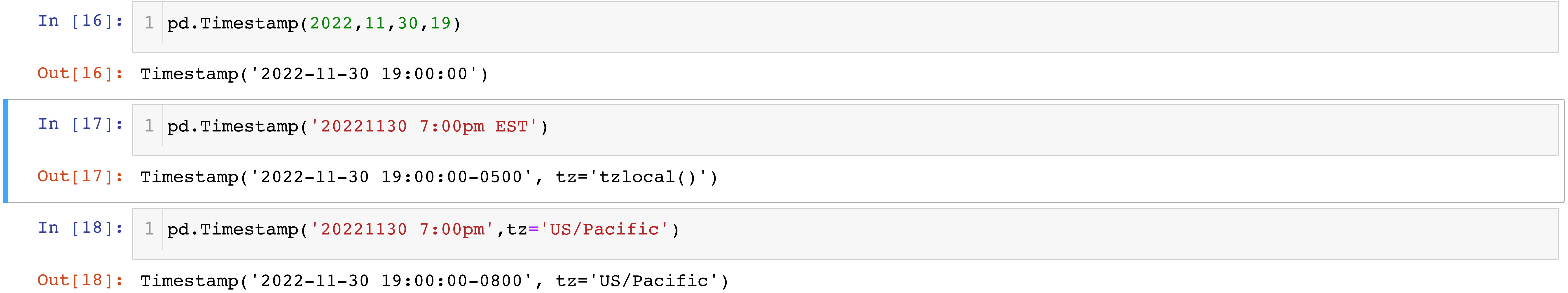


```
In [16]: pd.Timestamp(2022,11,30,19)

Out[16]: Timestamp('2022-11-30 19:00:00')
```

`pandas.Timestamp`

- like `datetime.datetime`
- can include **timezone** and **frequency** info
- can handle a missing time: `NaT`
- can be used anywhere `datetime` can be used
- an array of Timestamps can be used as an index



```
In [16]: pd.Timestamp(2022,11,30,19)

Out[16]: Timestamp('2022-11-30 19:00:00')

In [17]: pd.Timestamp('20221130 7:00pm EST')

Out[17]: Timestamp('2022-11-30 19:00:00-0500', tz='tzlocal()')

In [18]: pd.Timestamp('20221130 7:00pm',tz='US/Pacific')

Out[18]: Timestamp('2022-11-30 19:00:00-0800', tz='US/Pacific')
```

`pandas.Timestamp`

- like `datetime.datetime`
- can include **timezone** and **frequency** info
- can handle a missing time: `NaT`
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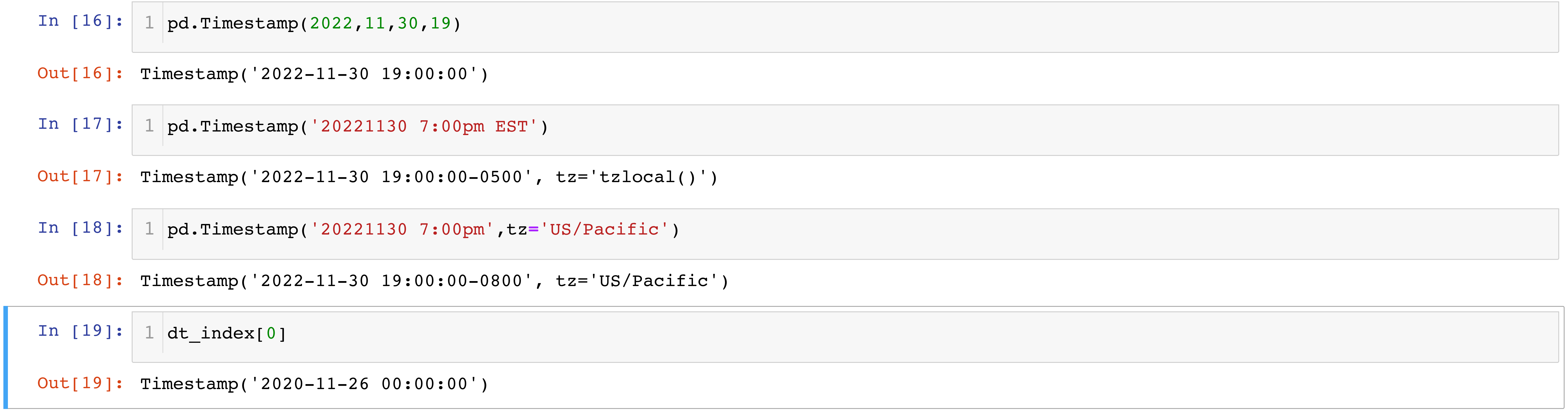

```
In [16]:  pd.Timestamp(2022,11,30,19)

Out[16]:  Timestamp('2022-11-30 19:00:00')

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Out[17]:  Timestamp('2022-11-30 19:00:00-0500', tz='tzlocal()')

In [18]:  pd.Timestamp('20221130 7:00pm',tz='US/Pacific')

Out[18]:  Timestamp('2022-11-30 19:00:00-0800', tz='US/Pacific')

In [19]:  dt_index[0]

Out[19]:  Timestamp('2020-11-26 00:00:00')
```
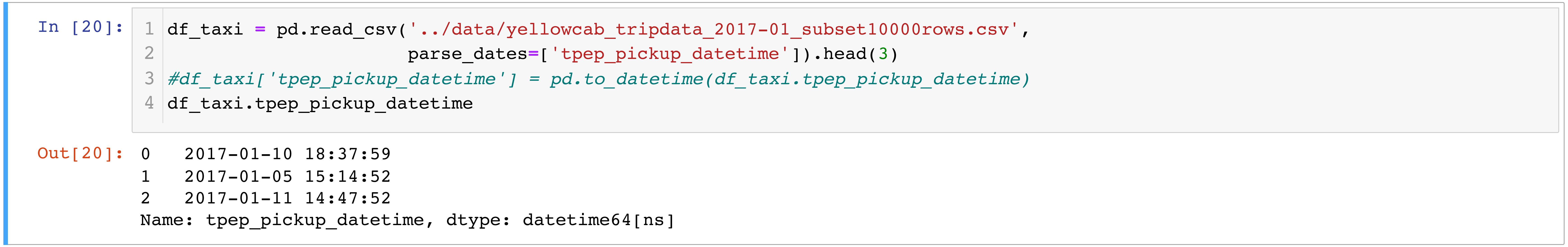

Accessing Datetime Components with `.dt`

Accessing Datetime Components with `.dt`



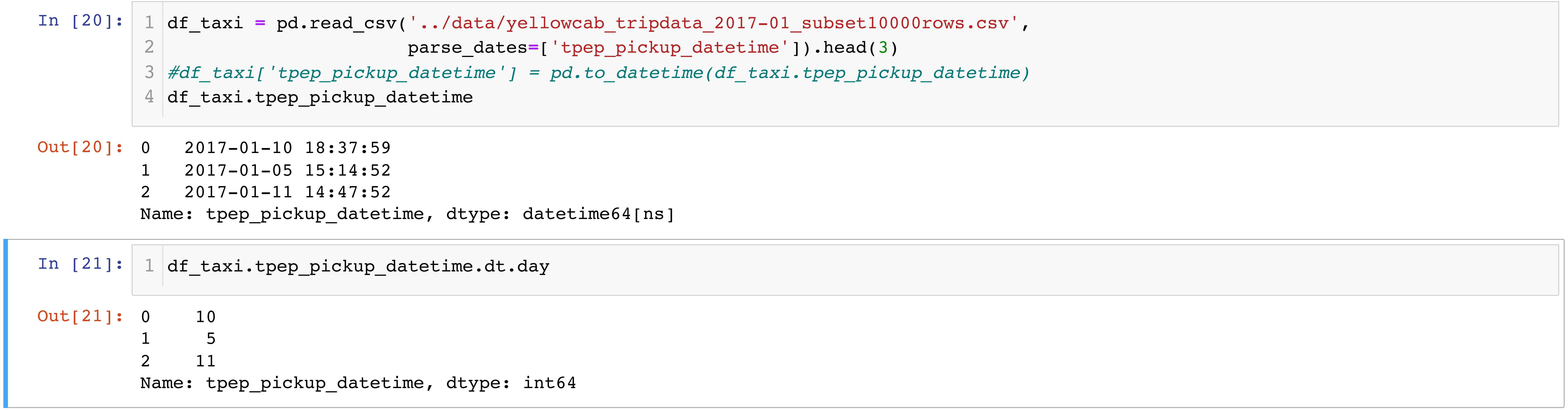
In [20]:

```python
df_taxi = pd.read_csv('../data/yellowcab_tripdata_2017-01_subset10000rows.csv',
                      parse_dates=['tpep_pickup_datetime']).head(3)
#df_taxi['tpep_pickup_datetime'] = pd.to_datetime(df_taxi.tpep_pickup_datetime)
df_taxi.tpep_pickup_datetime
```

Out[20]:

```
0   2017-01-10 18:37:59
1   2017-01-05 15:14:52
2   2017-01-11 14:47:52
Name: tpep_pickup_datetime, dtype: datetime64[ns]
```

Accessing Datetime Components with `.dt`



```
In [20]:
df_taxi = pd.read_csv('../data/yellowcab_tripdata_2017-01_subset10000rows.csv',
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df_taxi.tpep_pickup_datetime
```
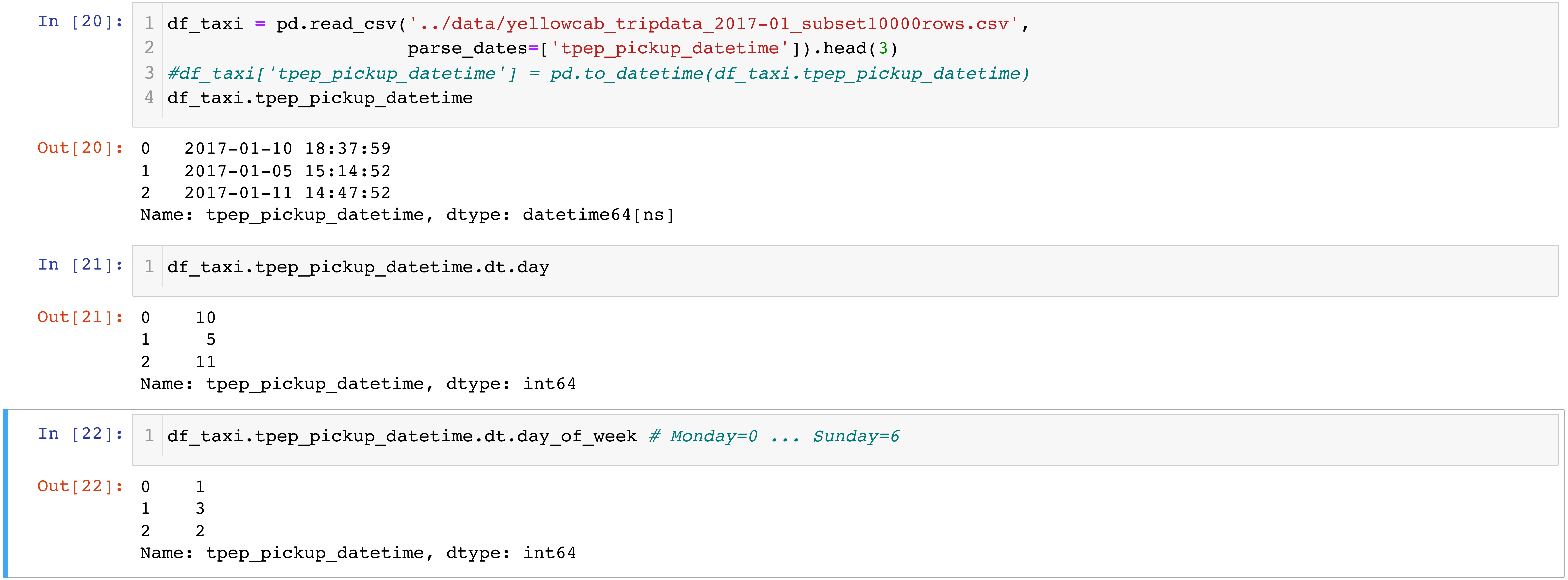

```
Out[20]:
0   2017-01-10 18:37:59
1   2017-01-05 15:14:52
2   2017-01-11 14:47:52
Name: tpep_pickup_datetime, dtype: datetime64[ns]
```

```
In [21]:
df_taxi.tpep_pickup_datetime.dt.day
```

```
Out[21]:
0    10
1     5
2    11
Name: tpep_pickup_datetime, dtype: int64
```

Accessing Datetime Components with `.dt`



In [20]:

```python
df_taxi = pd.read_csv('../data/yellowcab_tripdata_2017-01_subset10000rows.csv',
                      parse_dates=['tpep_pickup_datetime']).head(3)
#df_taxi['tpep_pickup_datetime'] = pd.to_datetime(df_taxi.tpep_pickup_datetime)
df_taxi.tpep_pickup_datetime
```

Out[20]:

```
0   2017-01-10 18:37:59
1   2017-01-05 15:14:52
2   2017-01-11 14:47:52
Name: tpep_pickup_datetime, dtype: datetime64[ns]
```

In [21]:

```python
df_taxi.tpep_pickup_datetime.dt.day
```

Out[21]:

```
0    10
1     5
2    11
Name: tpep_pickup_datetime, dtype: int64
```

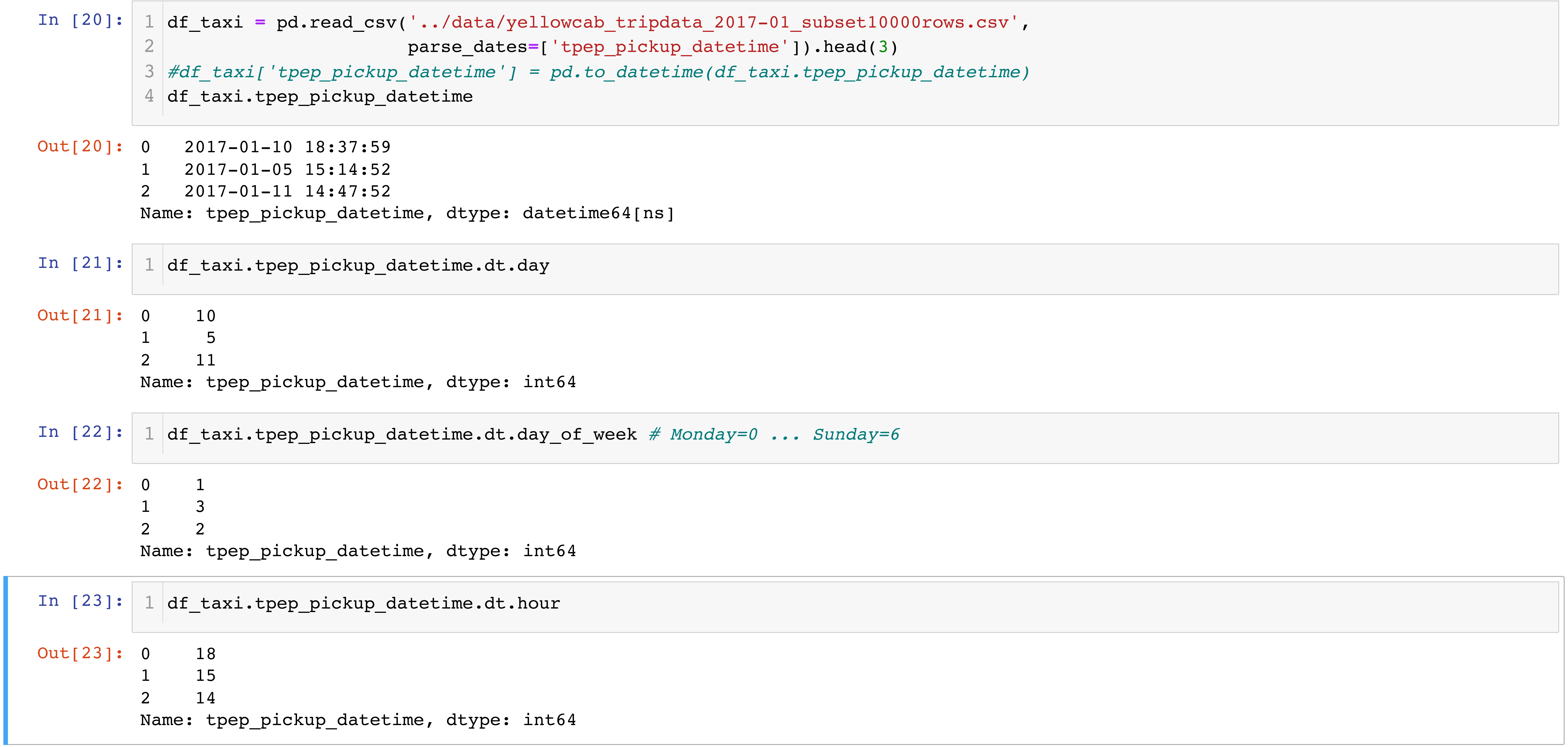
In [22]:

```python
df_taxi.tpep_pickup_datetime.dt.day_of_week # Monday=0 ... Sunday=6
```

Out[22]:

```
0    1
1    3
2    2
Name: tpep_pickup_datetime, dtype: int64
```

Accessing Datetime Components with `.dt`



In [20]:

```
df_taxi = pd.read_csv('../data/yellowcab_tripdata_2017-01_subset10000rows.csv',
                      parse_dates=['tpep_pickup_datetime']).head(3)
#df_taxi['tpep_pickup_datetime'] = pd.to_datetime(df_taxi.tpep_pickup_datetime)
df_taxi.tpep_pickup_datetime
```

Out[20]:

```
0   2017-01-10 18:37:59
1   2017-01-05 15:14:52
2   2017-01-11 14:47:52
Name: tpep_pickup_datetime, dtype: datetime64[ns]
```

In [21]:

```
df_taxi.tpep_pickup_datetime.dt.day
```

Out[21]:

```
0    10
1     5
2    11
Name: tpep_pickup_datetime, dtype: int64
```

In [22]:

```
df_taxi.tpep_pickup_datetime.dt.day_of_week # Monday=0 ... Sunday=6
```

Out[22]:

```
0    1
1    3
2    2
Name: tpep_pickup_datetime, dtype: int64
```

In [23]:

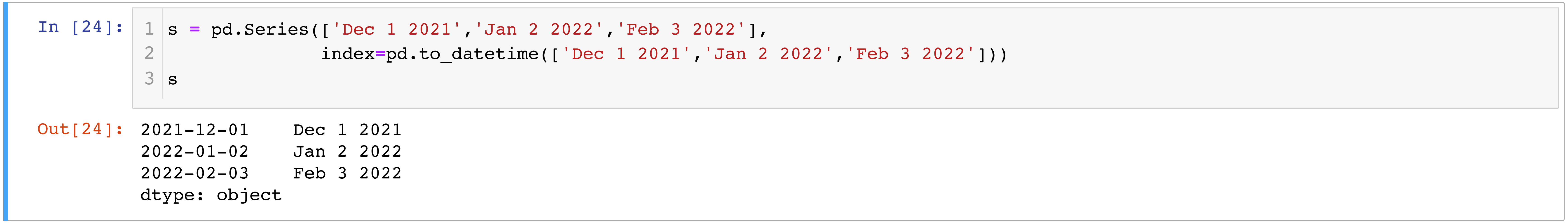
```
df_taxi.tpep_pickup_datetime.dt.hour
```

Out[23]:

```
0    18
1    15
2    14
Name: tpep_pickup_datetime, dtype: int64
```

DateIndex Indexing/Selecting/Slicing

DateIndex Indexing/Selecting/Slicing



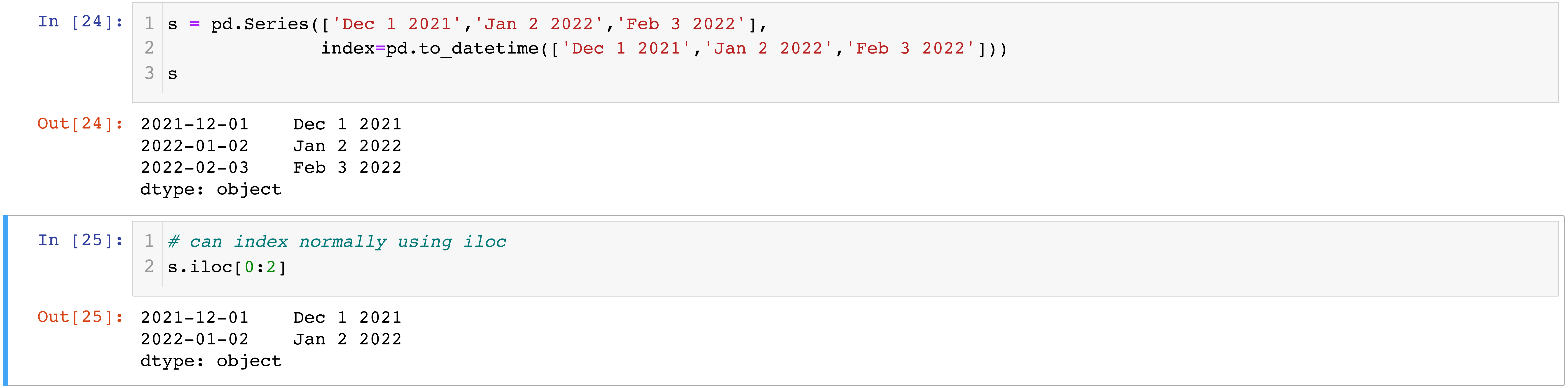
In [24]:

```
s = pd.Series(['Dec 1 2021','Jan 2 2022','Feb 3 2022'],
              index=pd.to_datetime(['Dec 1 2021','Jan 2 2022','Feb 3 2022']))
s
```

Out[24]:

```
2021-12-01    Dec 1 2021
2022-01-02    Jan 2 2022
2022-02-03    Feb 3 2022
dtype: object
```

DateIndex Indexing/Selecting/Slicing



In [24]:

```
s = pd.Series(['Dec 1 2021','Jan 2 2022','Feb 3 2022'],
              index=pd.to_datetime(['Dec 1 2021','Jan 2 2022','Feb 3 2022']))
s
```

Out[24]:

```
2021-12-01    Dec 1 2021
2022-01-02    Jan 2 2022
2022-02-03    Feb 3 2022
dtype: object
```

In [25]:

```
# can index normally using iloc
s.iloc[0:2]
```

Out[25]:

```
2021-12-01    Dec 1 2021
2022-01-02    Jan 2 2022
dtype: object
```

DateIndex Indexing/Selecting/Slicing Cont.

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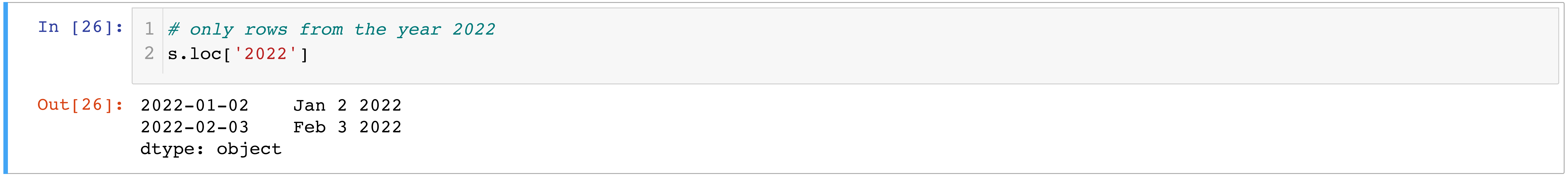


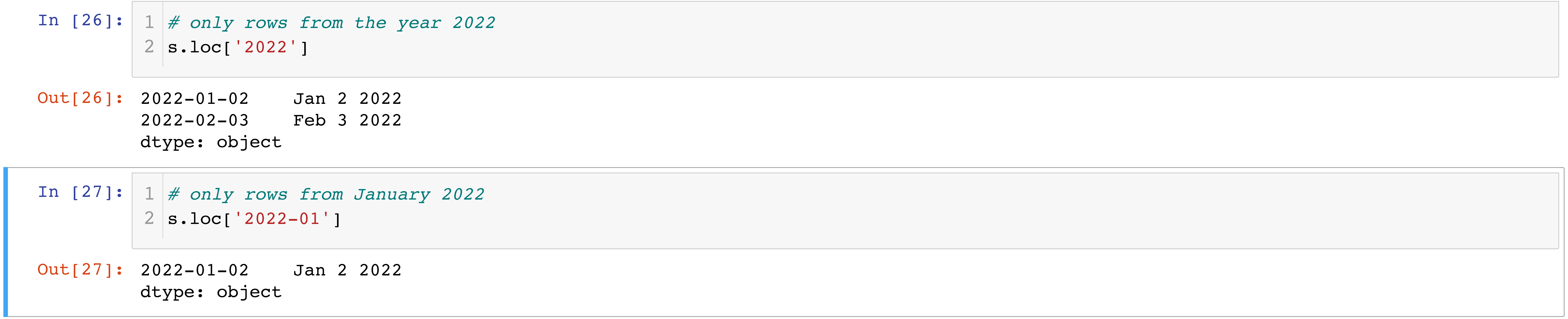
In [26]:

```
# only rows from the year 2022
s.loc['2022']
```

Out[26]:

```
2022-01-02    Jan 2 2022
2022-02-03    Feb 3 2022
dtype: object
```

DateIndex Indexing/Selecting/Slicing Cont.



In [26]:

```
# only rows from the year 2022
s.loc['2022']
```

Out[26]:

```
2022-01-02    Jan 2 2022
2022-02-03    Feb 3 2022
dtype: object
```

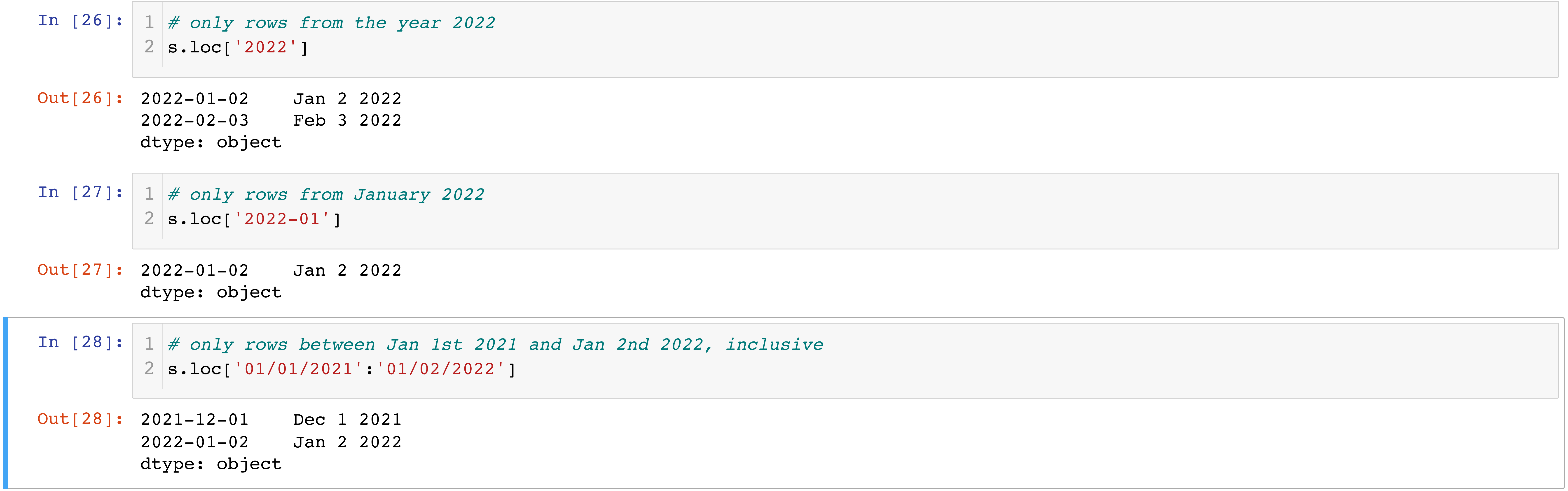
In [27]:

```
# only rows from January 2022
s.loc['2022-01']
```

Out[27]:

```
2022-01-02    Jan 2 2022
dtype: object
```

DateIndex Indexing/Selecting/Slicing Cont.



In [26]:

```python
# only rows from the year 2022
s.loc['2022']
```

Out[26]:

```
2022-01-02    Jan 2 2022
2022-02-03    Feb 3 2022
dtype: object
```

In [27]:

```python
# only rows from January 2022
s.loc['2022-01']
```

Out[27]:

```
2022-01-02    Jan 2 2022
dtype: object
```

In [28]:

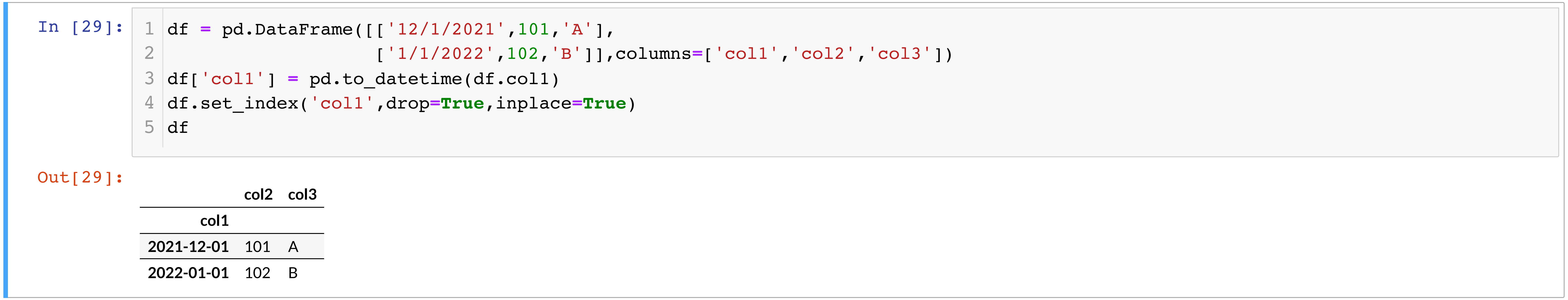
```python
# only rows between Jan 1st 2021 and Jan 2nd 2022, inclusive
s.loc['01/01/2021':'01/02/2022']
```

Out[28]:

```
2021-12-01    Dec 1 2021
2022-01-02    Jan 2 2022
dtype: object
```

Datetimes in DataFrames

Datetimes in DataFrames



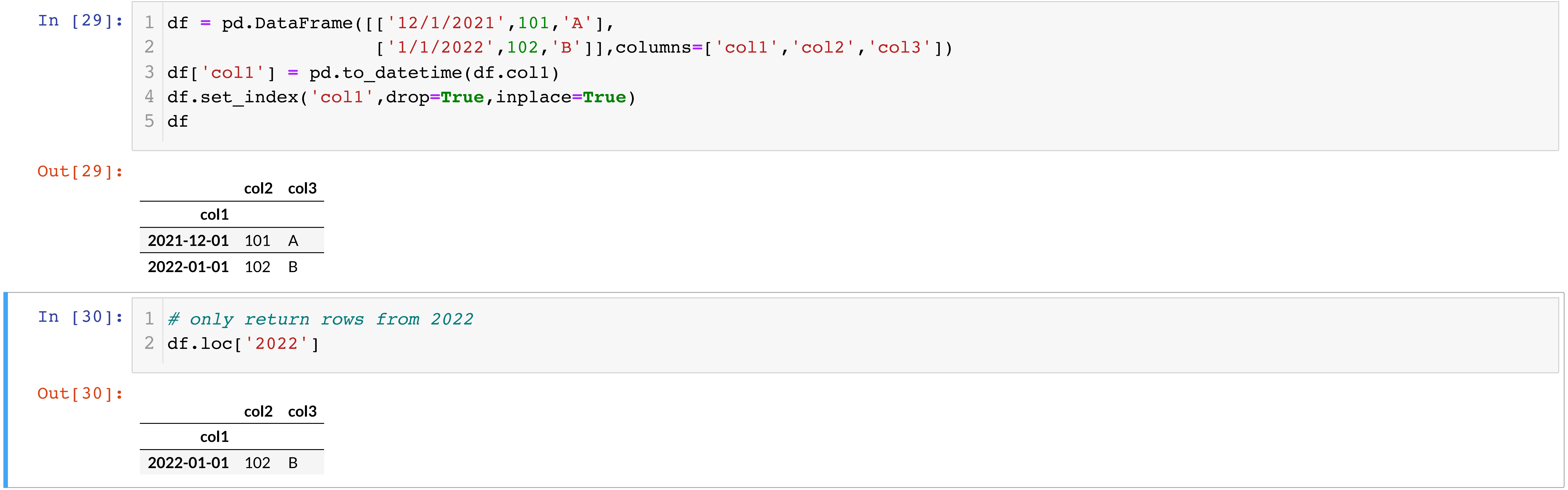
In [29]:

```python
df = pd.DataFrame([['12/1/2021',101,'A'],
                   ['1/1/2022',102,'B']],columns=['col1','col2','col3'])
df['col1'] = pd.to_datetime(df.col1)
df.set_index('col1',drop=True,inplace=True)
df
```

Out[29]:

```
            col2  col3
      col1
2021-12-01   101  A
2022-01-01   102  B
```

Datetimes in DataFrames



In [29]:

```
df = pd.DataFrame([['12/1/2021',101,'A'],
                   ['1/1/2022',102,'B']],columns=['col1','col2','col3'])
df['col1'] = pd.to_datetime(df.col1)
df.set_index('col1',drop=True,inplace=True)
df
```

Out[29]:

	col2	col3
col1		
2021-12-01	101	A
2022-01-01	102	B

In [30]:

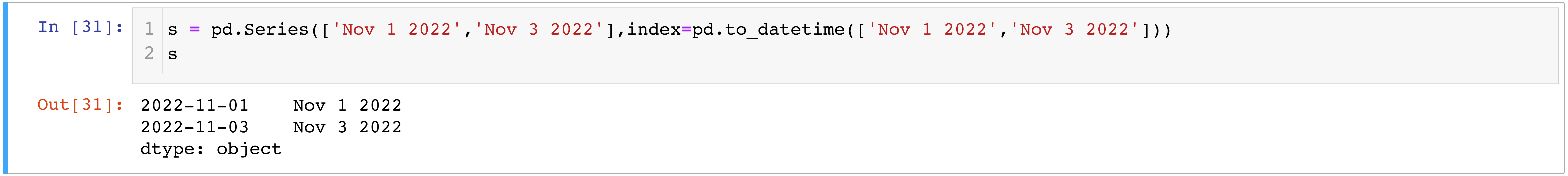
```
# only return rows from 2022
df.loc['2022']
```

Out[30]:

	col2	col3
col1		
2022-01-01	102	B

Timestamp Index: Setting Frequency

Timestamp Index: Setting Frequency



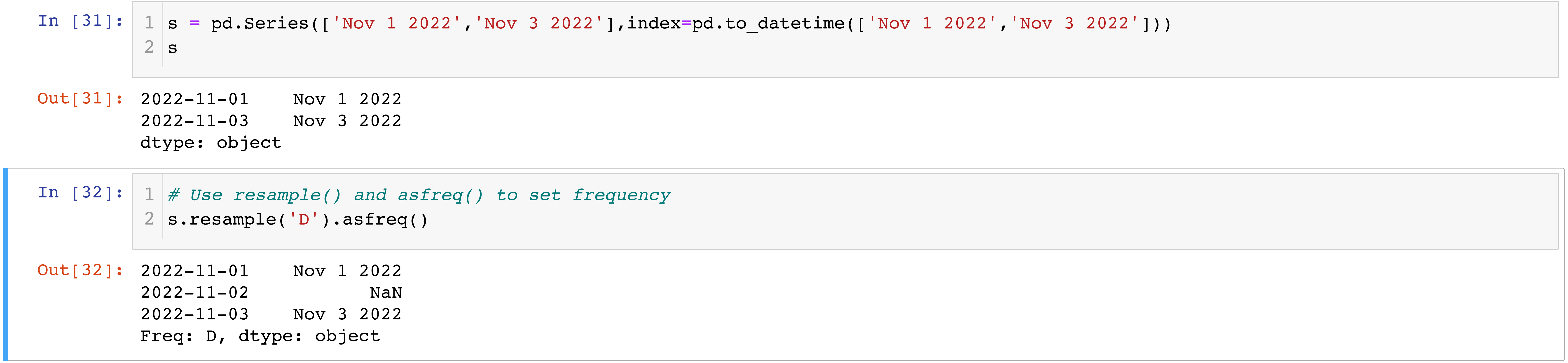
In [31]:

```
s = pd.Series(['Nov 1 2022','Nov 3 2022'],index=pd.to_datetime(['Nov 1 2022','Nov 3 2022']))
s
```

Out[31]:

```
2022-11-01    Nov 1 2022
2022-11-03    Nov 3 2022
dtype: object
```

Timestamp Index: Setting Frequency



In [31]:

```
s = pd.Series(['Nov 1 2022','Nov 3 2022'],index=pd.to_datetime(['Nov 1 2022','Nov 3 2022']))
s
```

Out[31]:

```
2022-11-01    Nov 1 2022
2022-11-03    Nov 3 2022
dtype: object
```

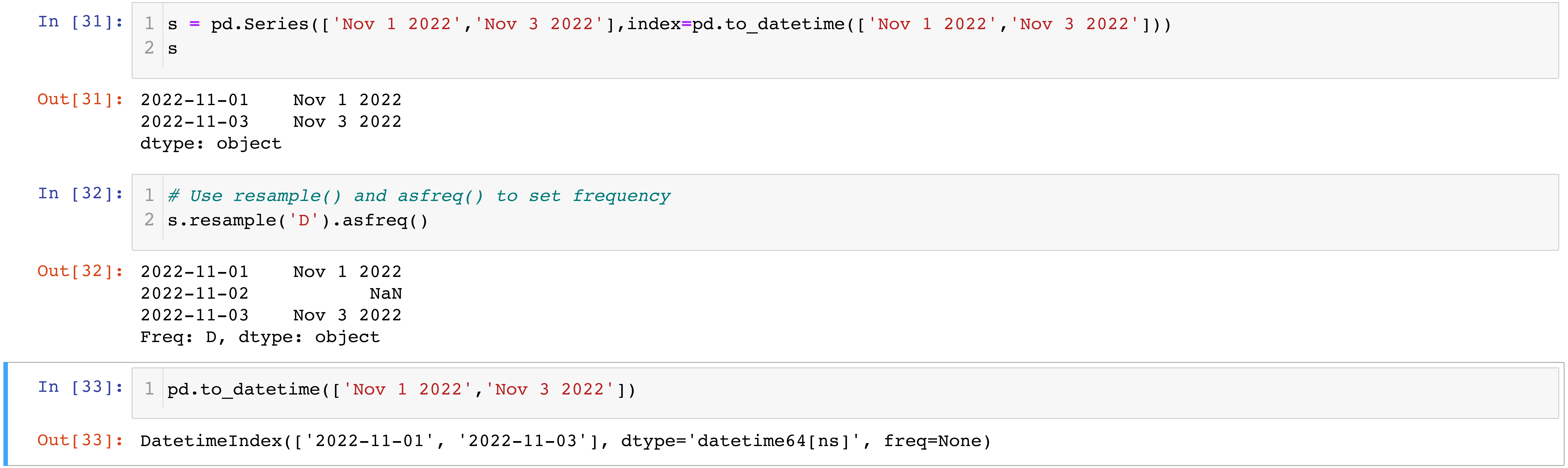
In [32]:

```
# Use resample() and asfreq() to set frequency
s.resample('D').asfreq()
```

Out[32]:

```
2022-11-01    Nov 1 2022
2022-11-02           NaN
2022-11-03    Nov 3 2022
Freq: D, dtype: object
```

Timestamp Index: Setting Frequency



```
In [31]: s = pd.Series(['Nov 1 2022','Nov 3 2022'],index=pd.to_datetime(['Nov 1 2022','Nov 3 2022']))
         s
```

```
Out[31]: 2022-11-01    Nov 1 2022
         2022-11-03    Nov 3 2022
         dtype: object
```

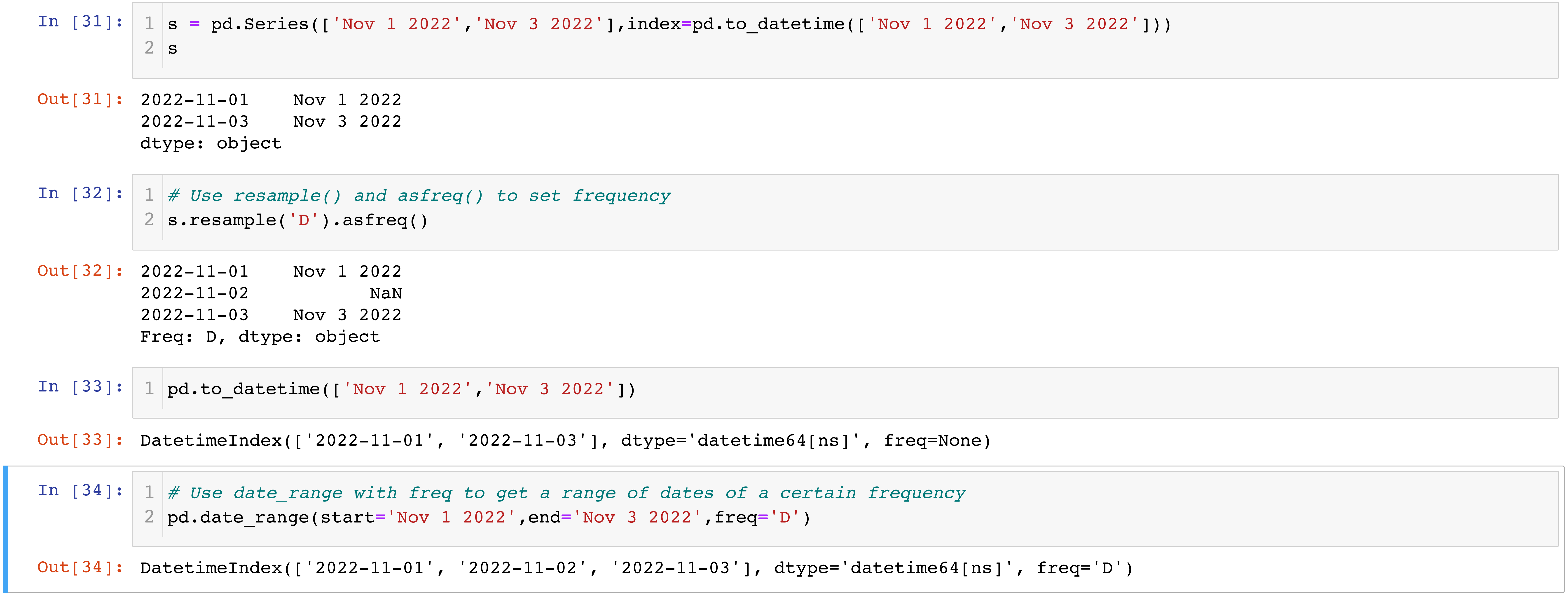
```
In [32]: # Use resample() and asfreq() to set frequency
         s.resample('D').asfreq()
```

```
Out[32]: 2022-11-01    Nov 1 2022
         2022-11-02           NaN
         2022-11-03    Nov 3 2022
         Freq: D, dtype: object
```

```
In [33]: pd.to_datetime(['Nov 1 2022','Nov 3 2022'])
```

```
Out[33]: DatetimeIndex(['2022-11-01', '2022-11-03'], dtype='datetime64[ns]', freq=None)
```

Timestamp Index: Setting Frequency



In [31]:

```
s = pd.Series(['Nov 1 2022','Nov 3 2022'],index=pd.to_datetime(['Nov 1 2022','Nov 3 2022']))
s
```

Out[31]:

```
2022-11-01    Nov 1 2022
2022-11-03    Nov 3 2022
dtype: object
```

In [32]:

```
# Use resample() and asfreq() to set frequency
s.resample('D').asfreq()
```

Out[32]:

```
2022-11-01    Nov 1 2022
2022-11-02           NaN
2022-11-03    Nov 3 2022
Freq: D, dtype: object
```

In [33]:

```
pd.to_datetime(['Nov 1 2022','Nov 3 2022'])
```

Out[33]:

```
DatetimeIndex(['2022-11-01', '2022-11-03'], dtype='datetime64[ns]', freq=None)
```

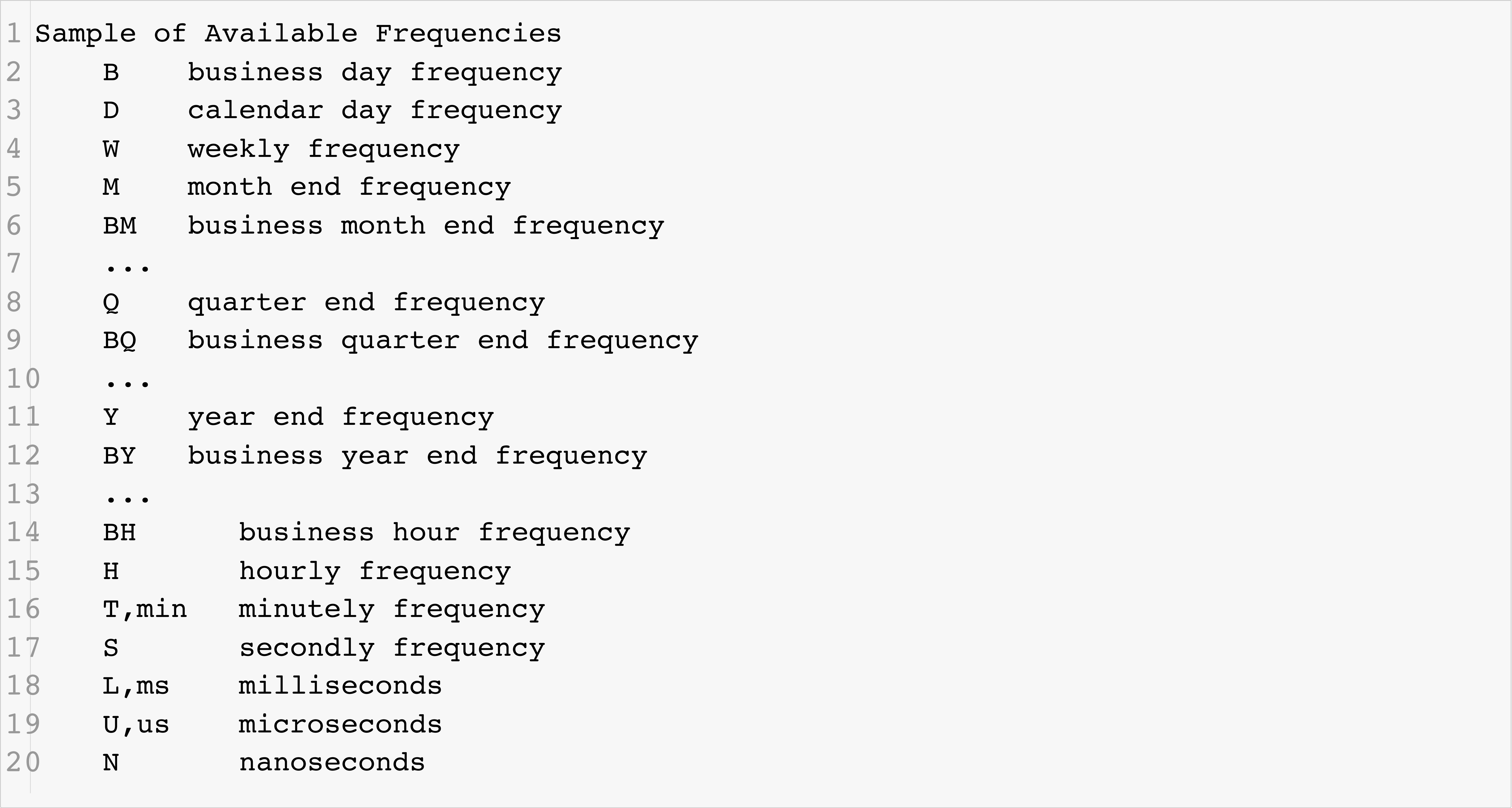
In [34]:

```
# Use date_range with freq to get a range of dates of a certain frequency
pd.date_range(start='Nov 1 2022',end='Nov 3 2022',freq='D')
```

Out[34]:

```
DatetimeIndex(['2022-11-01', '2022-11-02', '2022-11-03'], dtype='datetime64[ns]', freq='D')
```

```
Sample of Available Frequencies
    B    business day frequency
    D    calendar day frequency
    W    weekly frequency
    M    month end frequency
    BM   business month end frequency
    ...
    Q    quarter end frequency
    BQ   business quarter end frequency
    ...
    Y    year end frequency
    BY   business year end frequency
    ...
    BH      business hour frequency
    H       hourly frequency
    T,min   minutely frequency
    S       secondly frequency
    L,ms    milliseconds
    U,us    microseconds
    N       nanoseconds
```



```
Sample of Available Frequencies
    B    business day frequency
    D    calendar day frequency
    W    weekly frequency
    M    month end frequency
    BM   business month end frequency
    ...
    Q    quarter end frequency
    BQ   business quarter end frequency
    ...
    Y    year end frequency
    BY   business year end frequency
    ...
    BH      business hour frequency
    H       hourly frequency
    T,min   minutely frequency
    S       secondly frequency
    L,ms    milliseconds
    U,us    microseconds
    N       nanoseconds
```

https://pandas.pydata.org/pandas-docs/stable/user_guide/timeseries.html#timeseries-offset-aliases

Timezones

- Handled by `pytz` library

Timezones

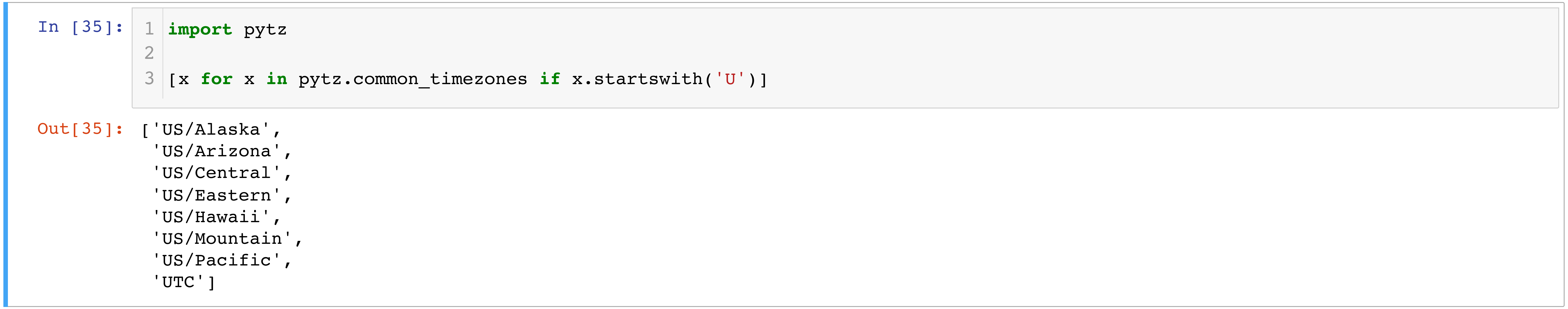
- Handled by `pytz` library

```
In [35]:
import pytz

[x for x in pytz.common_timezones if x.startswith('U')]
```

```
Out[35]: ['US/Alaska',
          'US/Arizona',
          'US/Central',
          'US/Eastern',
          'US/Hawaii',
          'US/Mountain',
          'US/Pacific',
          'UTC']
```

Timezones

- Handled by `pytz` library



In [35]:

```python
import pytz

[x for x in pytz.common_timezones if x.startswith('U')]
```

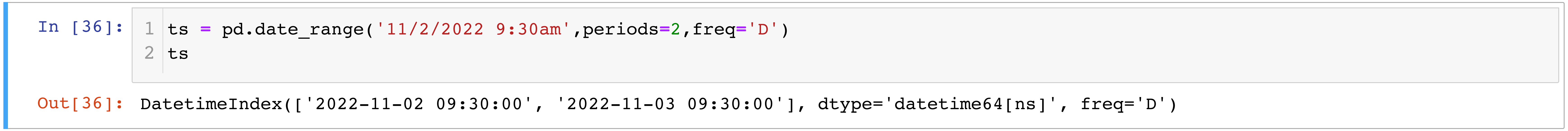
Out[35]:

```
['US/Alaska',
 'US/Arizona',
 'US/Central',
 'US/Eastern',
 'US/Hawaii',
 'US/Mountain',
 'US/Pacific',
 'UTC']
```

UTC: coordinated universal time (EST is 5 hours behind, -5:00)

Timezones Cont.

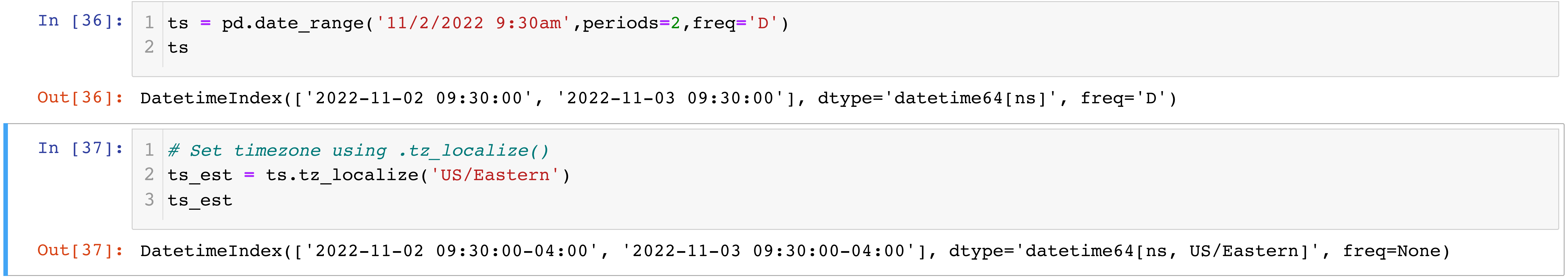
Timezones Cont.



```
In [36]: ts = pd.date_range('11/2/2022 9:30am',periods=2,freq='D')
         ts
```

```
Out[36]: DatetimeIndex(['2022-11-02 09:30:00', '2022-11-03 09:30:00'], dtype='datetime64[ns]', freq='D')
```

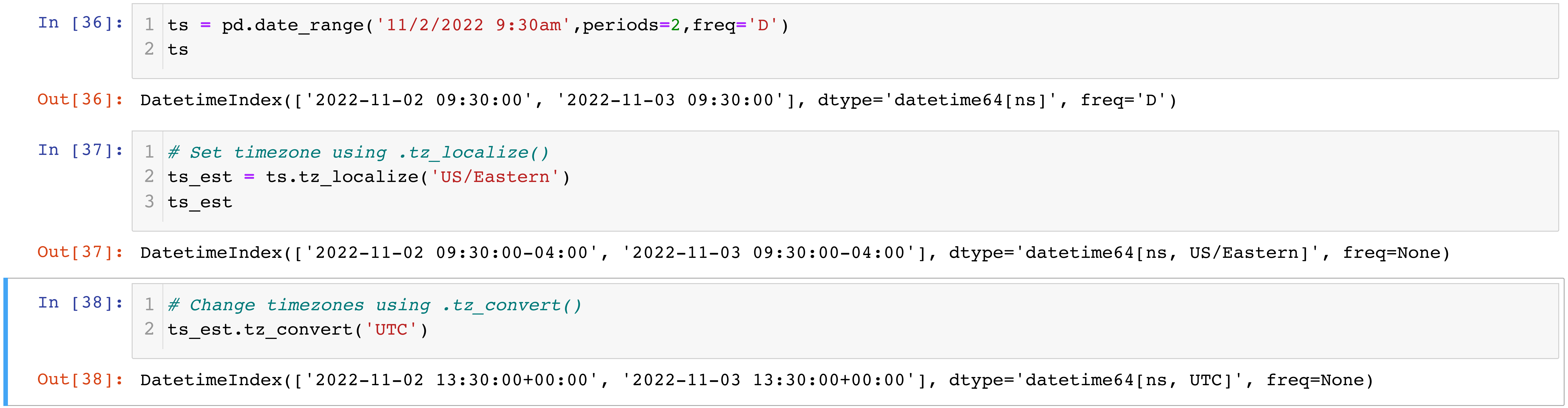
Timezones Cont.



```
In [36]: ts = pd.date_range('11/2/2022 9:30am',periods=2,freq='D')
         ts

Out[36]: DatetimeIndex(['2022-11-02 09:30:00', '2022-11-03 09:30:00'], dtype='datetime64[ns]', freq='D')
```

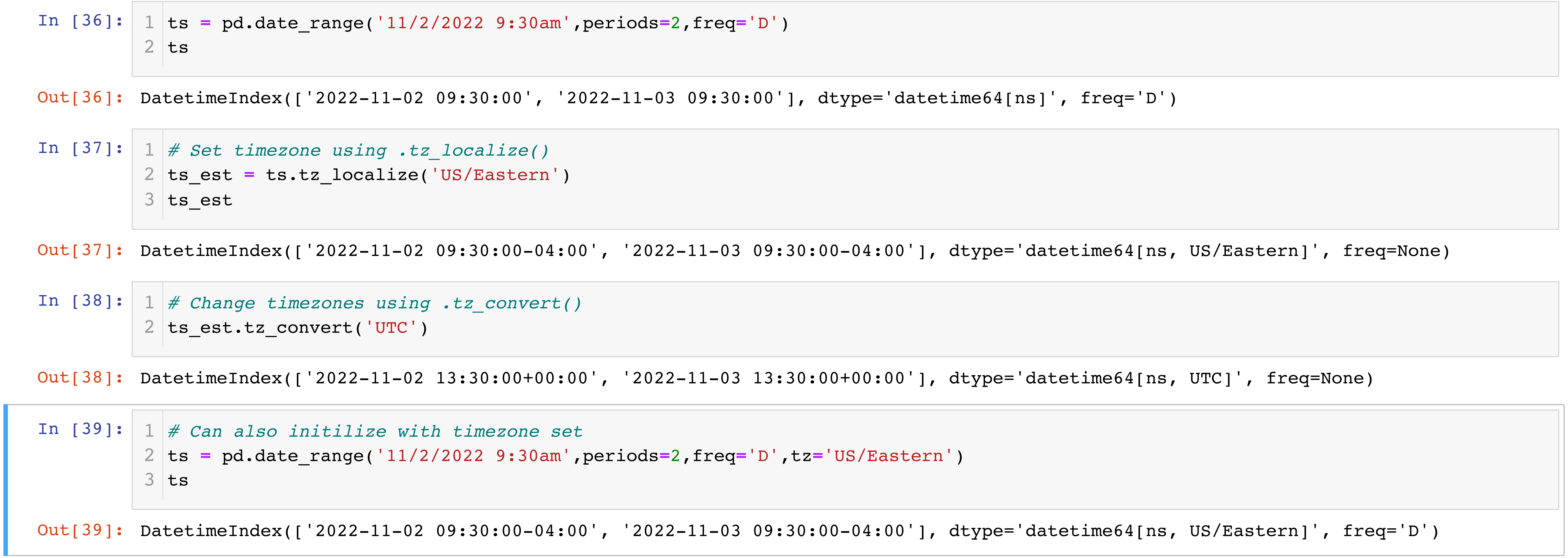
```
In [37]: # Set timezone using .tz_localize()
         ts_est = ts.tz_localize('US/Eastern')
         ts_est

Out[37]: DatetimeIndex(['2022-11-02 09:30:00-04:00', '2022-11-03 09:30:00-04:00'], dtype='datetime64[ns, US/Eastern]', freq=None)
```

Timezones Cont.



```
In [36]: ts = pd.date_range('11/2/2022 9:30am',periods=2,freq='D')
         ts

Out[36]: DatetimeIndex(['2022-11-02 09:30:00', '2022-11-03 09:30:00'], dtype='datetime64[ns]', freq='D')

In [37]: # Set timezone using .tz_localize()
         ts_est = ts.tz_localize('US/Eastern')
         ts_est

Out[37]: DatetimeIndex(['2022-11-02 09:30:00-04:00', '2022-11-03 09:30:00-04:00'], dtype='datetime64[ns, US/Eastern]', freq=None)

In [38]: # Change timezones using .tz_convert()
         ts_est.tz_convert('UTC')

Out[38]: DatetimeIndex(['2022-11-02 13:30:00+00:00', '2022-11-03 13:30:00+00:00'], dtype='datetime64[ns, UTC]', freq=None)
```

Timezones Cont.



```
In [36]: ts = pd.date_range('11/2/2022 9:30am',periods=2,freq='D')
         ts

Out[36]: DatetimeIndex(['2022-11-02 09:30:00', '2022-11-03 09:30:00'], dtype='datetime64[ns]', freq='D')
```

```
In [37]: # Set timezone using .tz_localize()
         ts_est = ts.tz_localize('US/Eastern')
         ts_est

Out[37]: DatetimeIndex(['2022-11-02 09:30:00-04:00', '2022-11-03 09:30:00-04:00'], dtype='datetime64[ns, US/Eastern]', freq=None)
```

```
In [38]: # Change timezones using .tz_convert()
         ts_est.tz_convert('UTC')

Out[38]: DatetimeIndex(['2022-11-02 13:30:00+00:00', '2022-11-03 13:30:00+00:00'], dtype='datetime64[ns, UTC]', freq=None)
```

```
In [39]: # Can also initilize with timezone set
         ts = pd.date_range('11/2/2022 9:30am',periods=2,freq='D',tz='US/Eastern')
         ts

Out[39]: DatetimeIndex(['2022-11-02 09:30:00-04:00', '2022-11-03 09:30:00-04:00'], dtype='datetime64[ns, US/Eastern]', freq='D')
```

Time Series in Python so far:

- `datetime .date .time .datetime .timedelta`
- format with `.strftime()`
- parse time with `pd.to_datetime()`
- `pandas Timestamp Timedelta DatetimeIndex`
- Indexing with `DatetimeIndex`
- Frequencies
- Timezones

Next: Operations on Time Series data

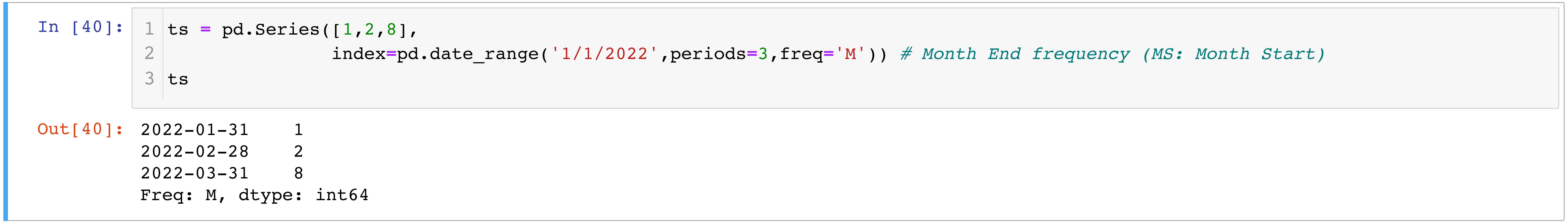
- Shifting
- Resampling
- Moving Windows

Shifting/Lagging

- Moving data backward or forward in time (lagging/leading)
- Ex: calculate percent change

Shifting/Lagging

- Moving data backward or forward in time (lagging/leading)
- Ex: calculate percent change



In [40]:

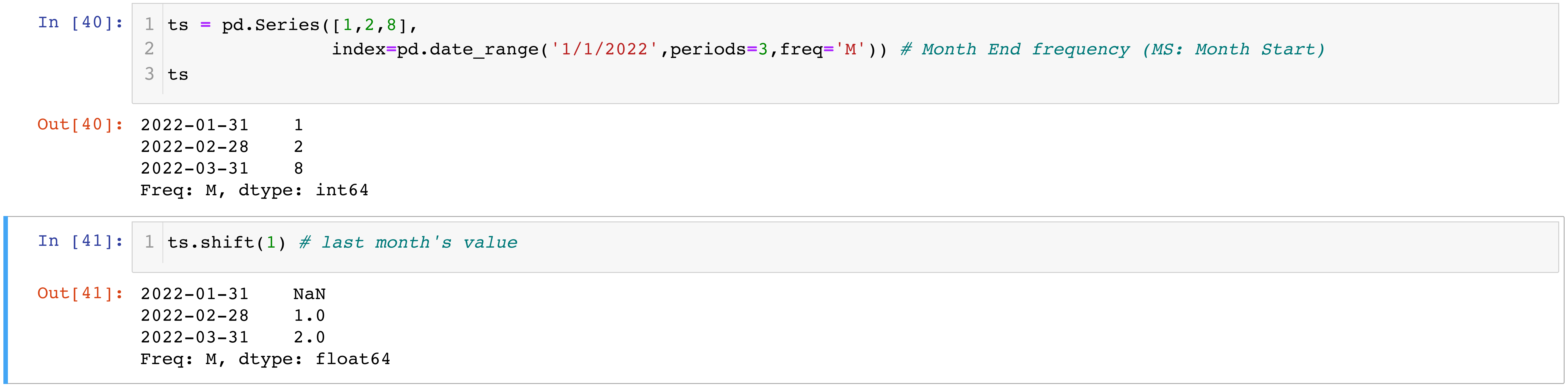
```python
ts = pd.Series([1,2,8],
               index=pd.date_range('1/1/2022',periods=3,freq='M')) # Month End frequency (MS: Month Start)
ts
```

Out[40]:

```
2022-01-31    1
2022-02-28    2
2022-03-31    8
Freq: M, dtype: int64
```

Shifting/Lagging

- Moving data backward or forward in time (lagging/leading)
- Ex: calculate percent change



In [40]:
```
ts = pd.Series([1,2,8],
               index=pd.date_range('1/1/2022',periods=3,freq='M')) # Month End frequency (MS: Month Start)
ts
```

Out[40]:
```
2022-01-31    1
2022-02-28    2
2022-03-31    8
Freq: M, dtype: int64
```

In [41]:
```
ts.shift(1) # last month's value
```

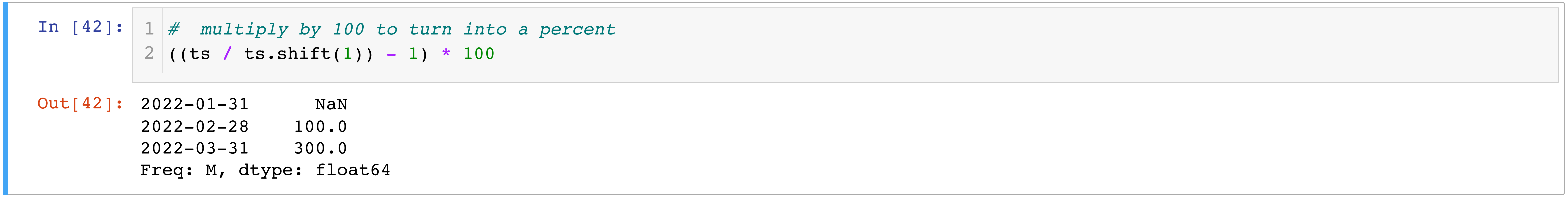
Out[41]:
```
2022-01-31    NaN
2022-02-28    1.0
2022-03-31    2.0
Freq: M, dtype: float64
```

Shifting

- **percent change**, use one of :
    - (new_value - old_value) / old_value
    - (new_value / old_value) - 1

Shifting

- **percent change**, use one of :
  - (new_value - old_value) / old_value
  - (new_value / old_value) - 1

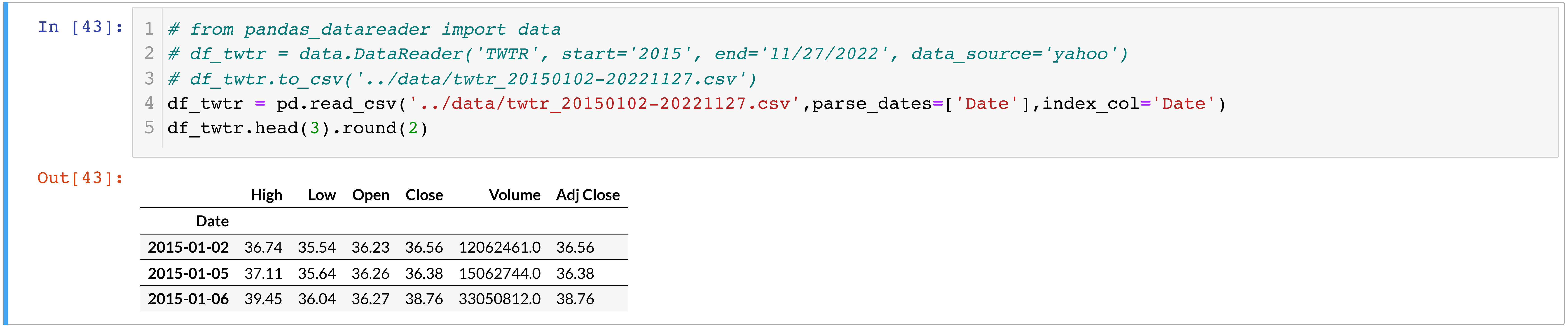


```python
#  multiply by 100 to turn into a percent
((ts / ts.shift(1)) - 1) * 100
```

```
2022-01-31      NaN
2022-02-28    100.0
2022-03-31    300.0
Freq: M, dtype: float64
```

Example Dataset: Twitter Stock

Example Dataset: Twitter Stock



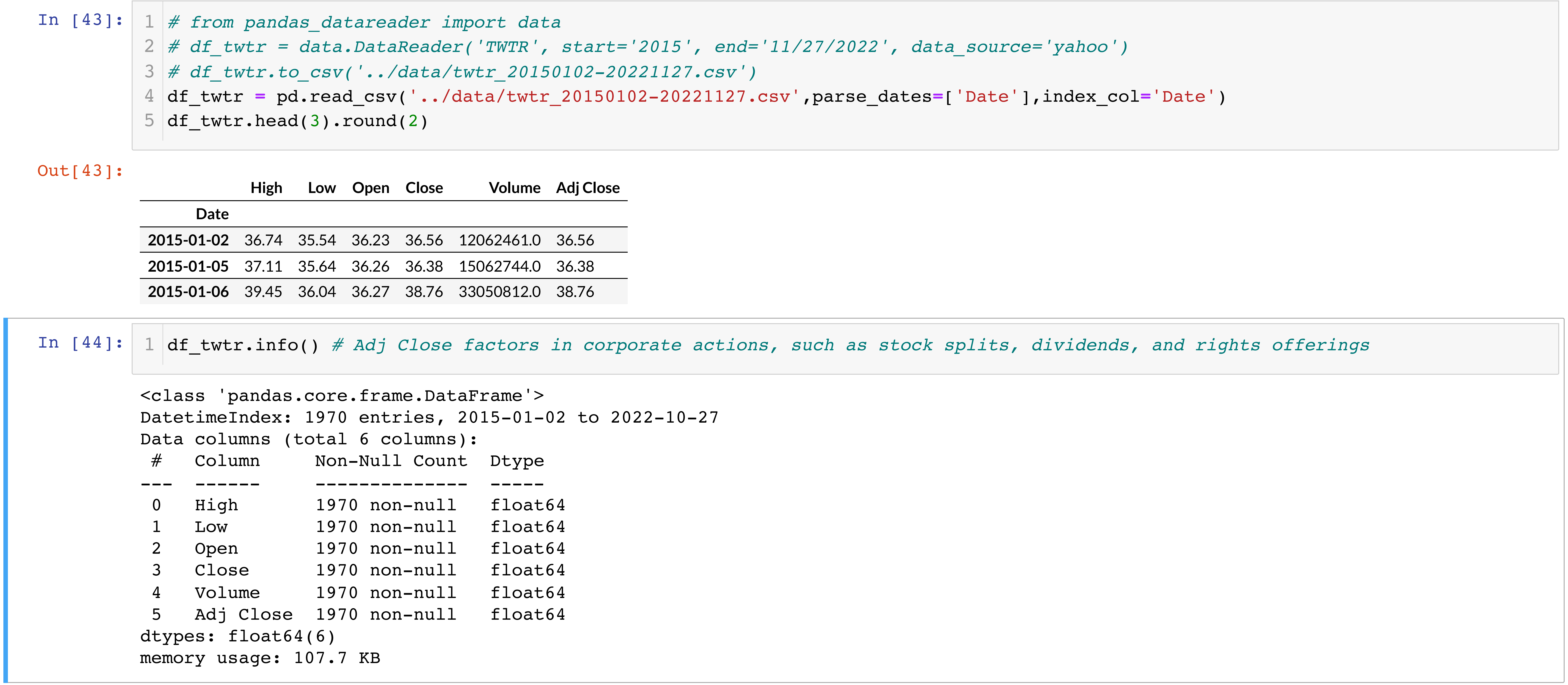
In [43]:

```
# from pandas_datareader import data
# df_twtr = data.DataReader('TWTR', start='2015', end='11/27/2022', data_source='yahoo')
# df_twtr.to_csv('../data/twtr_20150102-20221127.csv')
df_twtr = pd.read_csv('../data/twtr_20150102-20221127.csv',parse_dates=['Date'],index_col='Date')
df_twtr.head(3).round(2)
```

Out[43]:

	High	Low	Open	Close	Volume	Adj Close
Date						
2015-01-02	36.74	35.54	36.23	36.56	12062461.0	36.56
2015-01-05	37.11	35.64	36.26	36.38	15062744.0	36.38
2015-01-06	39.45	36.04	36.27	38.76	33050812.0	38.76

Example Dataset: Twitter Stock



In [43]:

```
# from pandas_datareader import data
# df_twtr = data.DataReader('TWTR', start='2015', end='11/27/2022', data_source='yahoo')
# df_twtr.to_csv('../data/twtr_20150102-20221127.csv')
df_twtr = pd.read_csv('../data/twtr_20150102-20221127.csv',parse_dates=['Date'],index_col='Date')
df_twtr.head(3).round(2)
```

Out[43]:

	High	Low	Open	Close	Volume	Adj Close
Date						
2015-01-02	36.74	35.54	36.23	36.56	12062461.0	36.56
2015-01-05	37.11	35.64	36.26	36.38	15062744.0	36.38
2015-01-06	39.45	36.04	36.27	38.76	33050812.0	38.76

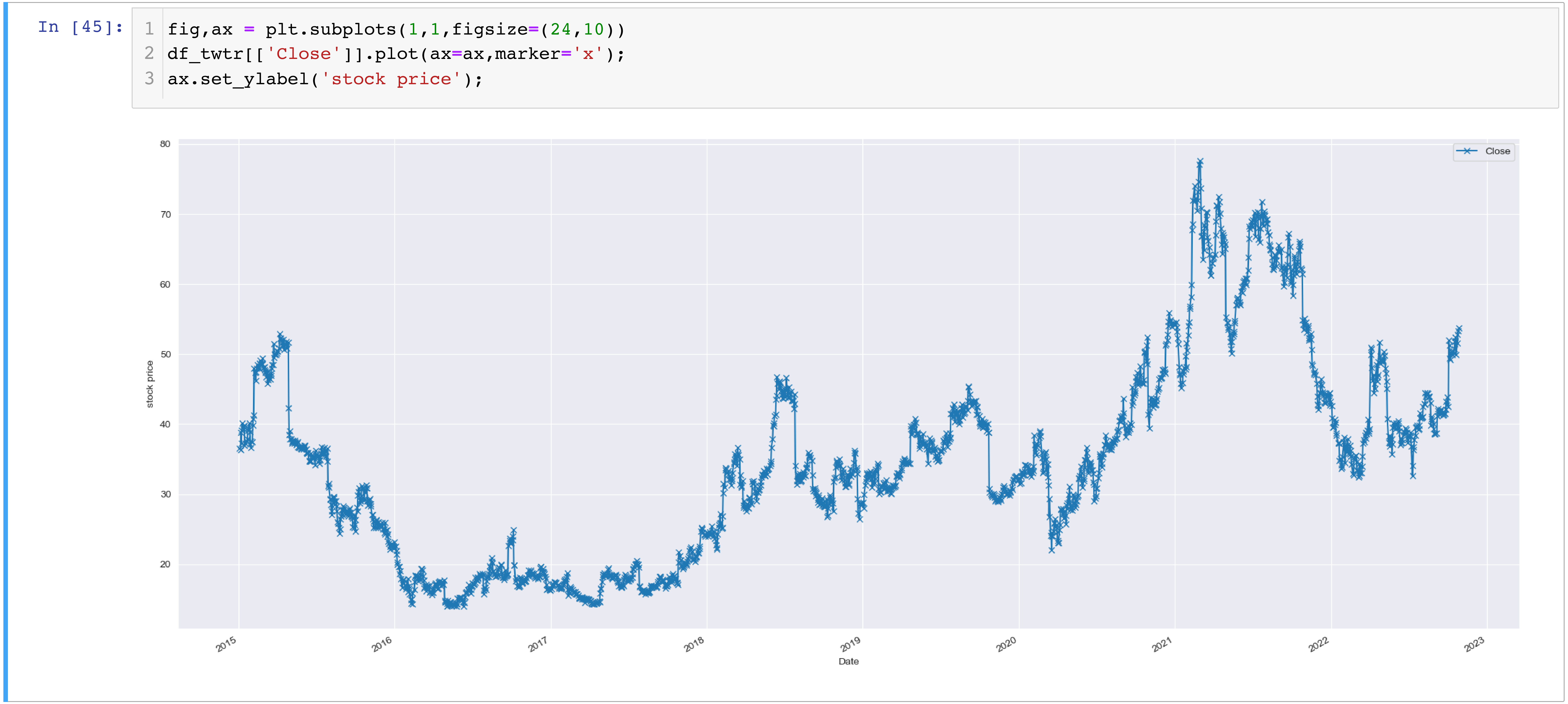
In [44]:

```
df_twtr.info() # Adj Close factors in corporate actions, such as stock splits, dividends, and rights offerings
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 1970 entries, 2015-01-02 to 2022-10-27
Data columns (total 6 columns):
 #   Column     Non-Null Count  Dtype  
---  ------     --------------  -----  
 0   High       1970 non-null   float64
 1   Low        1970 non-null   float64
 2   Open       1970 non-null   float64
 3   Close      1970 non-null   float64
 4   Volume     1970 non-null   float64
 5   Adj Close  1970 non-null   float64
dtypes: float64(6)
memory usage: 107.7 KB
```

Example Dataset: Twitter Stock

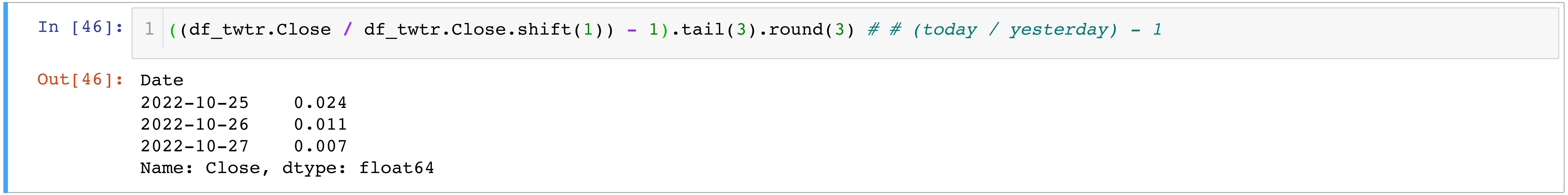
Example Dataset: Twitter Stock



```
fig,ax = plt.subplots(1,1,figsize=(24,10))
df_twtr[['Close']].plot(ax=ax,marker='x');
ax.set_ylabel('stock price');
```

Shifting Example: Percent Change Twitter Close

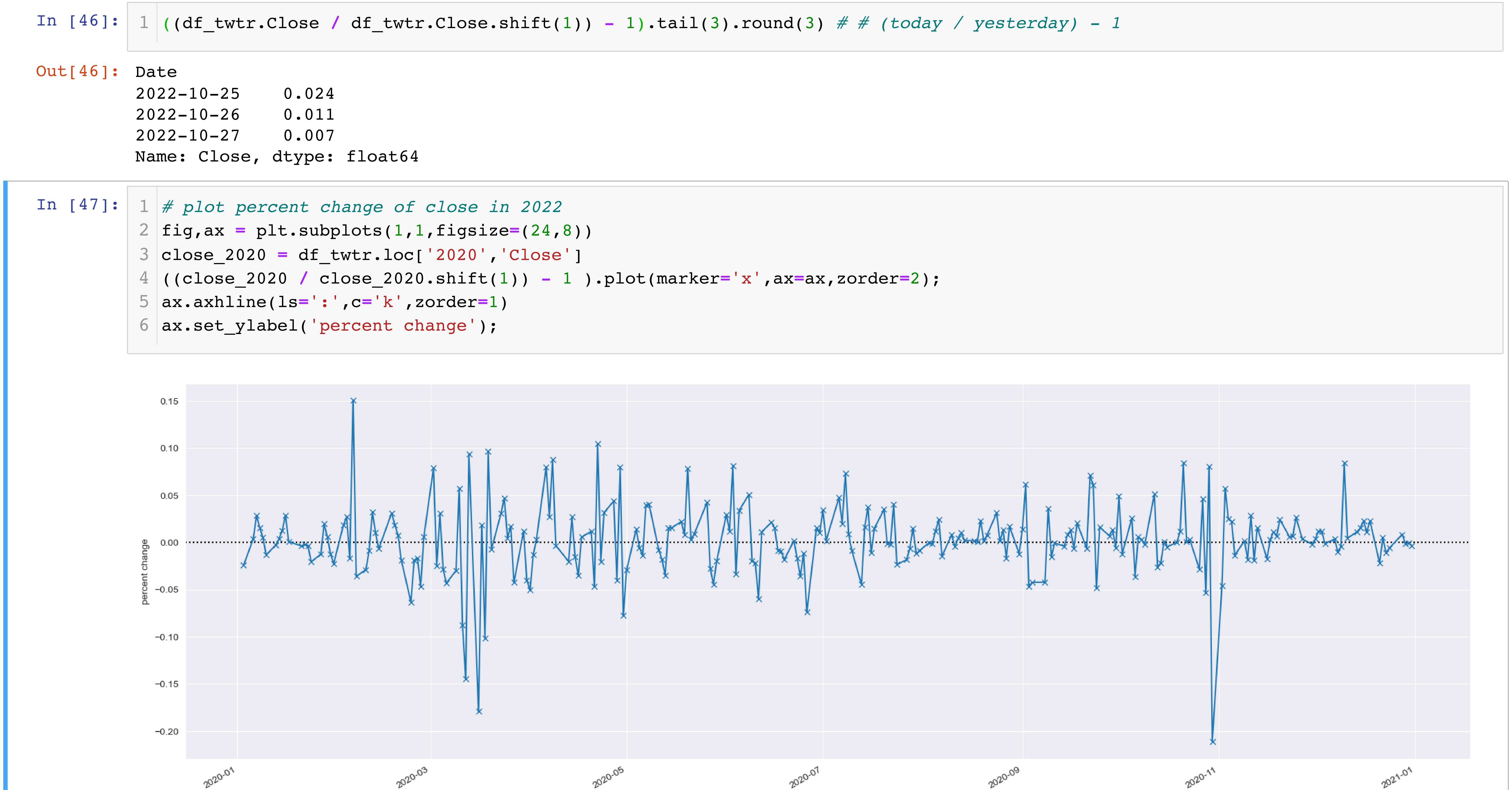
Shifting Example: Percent Change Twitter Close



```
In [46]: ((df_twtr.Close / df_twtr.Close.shift(1)) - 1).tail(3).round(3) # # (today / yesterday) - 1
```

```
Out[46]: Date
         2022-10-25    0.024
         2022-10-26    0.011
         2022-10-27    0.007
         Name: Close, dtype: float64
```

Shifting Example: Percent Change Twitter Close



```
In [46]: ((df_twtr.Close / df_twtr.Close.shift(1)) - 1).tail(3).round(3) # # (today / yesterday) - 1
```

```
Out[46]: Date
         2022-10-25    0.024
         2022-10-26    0.011
         2022-10-27    0.007
         Name: Close, dtype: float64
```

```
In [47]: # plot percent change of close in 2022
         fig,ax = plt.subplots(1,1,figsize=(24,8))
         close_2020 = df_twtr.loc['2020','Close']
         ((close_2020 / close_2020.shift(1)) - 1 ).plot(marker='x',ax=ax,zorder=2);
         ax.axhline(ls=':',c='k',zorder=1)
         ax.set_ylabel('percent change');
```

Resampling

- Convert from one frequency to another

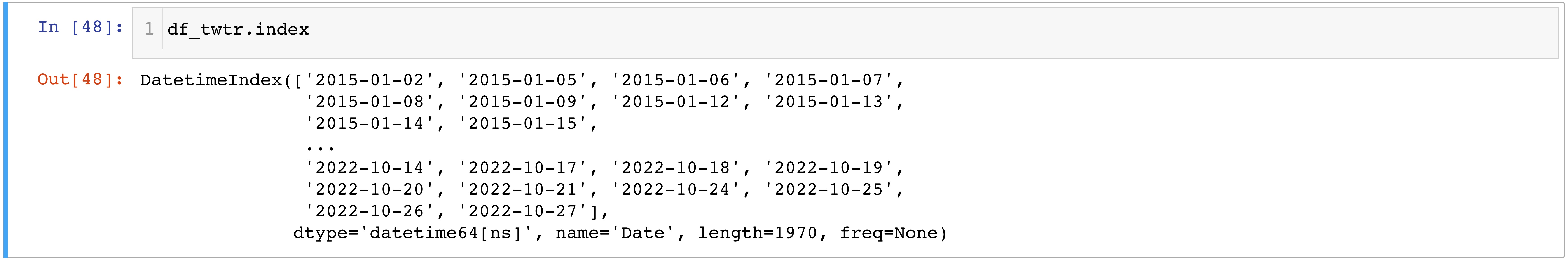
- **Downsampling**
  - from higher to lower (day to month)
  - need to aggregate

- **Upsampling**
  - from lower to higher (month to day)
  - need to fill missing

- **Can also be used to set frequency from None**

Resampling: Initialize Frequency

Resampling: Initialize Frequency



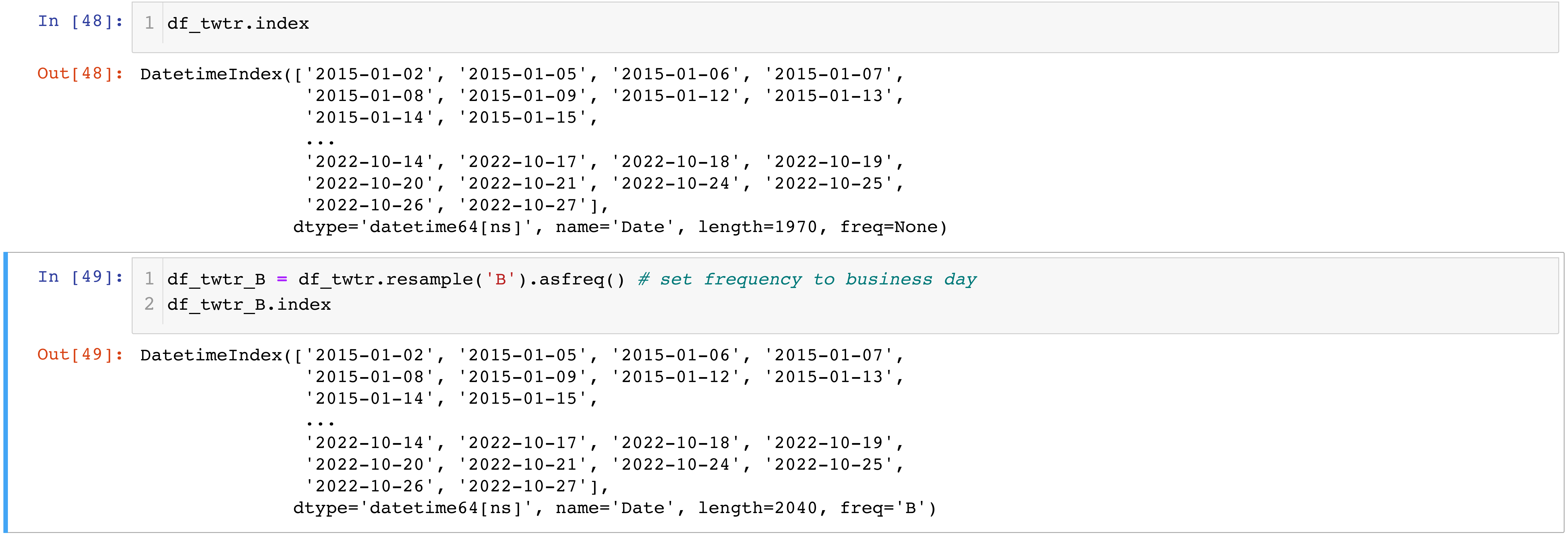
In [48]:

```
df_twtr.index
```

Out[48]:

```
DatetimeIndex(['2015-01-02', '2015-01-05', '2015-01-06', '2015-01-07',
               '2015-01-08', '2015-01-09', '2015-01-12', '2015-01-13',
               '2015-01-14', '2015-01-15',
               ...
               '2022-10-14', '2022-10-17', '2022-10-18', '2022-10-19',
               '2022-10-20', '2022-10-21', '2022-10-24', '2022-10-25',
               '2022-10-26', '2022-10-27'],
              dtype='datetime64[ns]', name='Date', length=1970, freq=None)
```

Resampling: Initialize Frequency



```
In [48]: df_twtr.index
```

```
Out[48]: DatetimeIndex(['2015-01-02', '2015-01-05', '2015-01-06', '2015-01-07',
                        '2015-01-08', '2015-01-09', '2015-01-12', '2015-01-13',
                        '2015-01-14', '2015-01-15',
                        ...
                        '2022-10-14', '2022-10-17', '2022-10-18', '2022-10-19',
                        '2022-10-20', '2022-10-21', '2022-10-24', '2022-10-25',
                        '2022-10-26', '2022-10-27'],
                       dtype='datetime64[ns]', name='Date', length=1970, freq=None)
```

```
In [49]: df_twtr_B = df_twtr.resample('B').asfreq() # set frequency to business day
         df_twtr_B.index
```

```
Out[49]: DatetimeIndex(['2015-01-02', '2015-01-05', '2015-01-06', '2015-01-07',
                        '2015-01-08', '2015-01-09', '2015-01-12', '2015-01-13',
                        '2015-01-14', '2015-01-15',
                        ...
                        '2022-10-14', '2022-10-17', '2022-10-18', '2022-10-19',
                        '2022-10-20', '2022-10-21', '2022-10-24', '2022-10-25',
                        '2022-10-26', '2022-10-27'],
                       dtype='datetime64[ns]', name='Date', length=2040, freq='B')
```

Resampling: Downsampling

- Go from higher/shorter to lower/longer
- Need to aggregate (like groupby)
- Example: Downsampling from business day to business quarter

Resampling: Downsampling

- Go from higher/shorter to lower/longer
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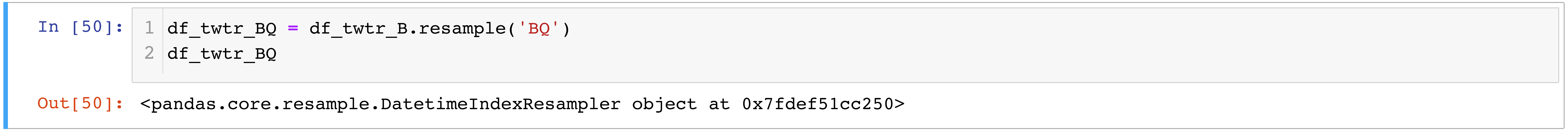


In [50]:

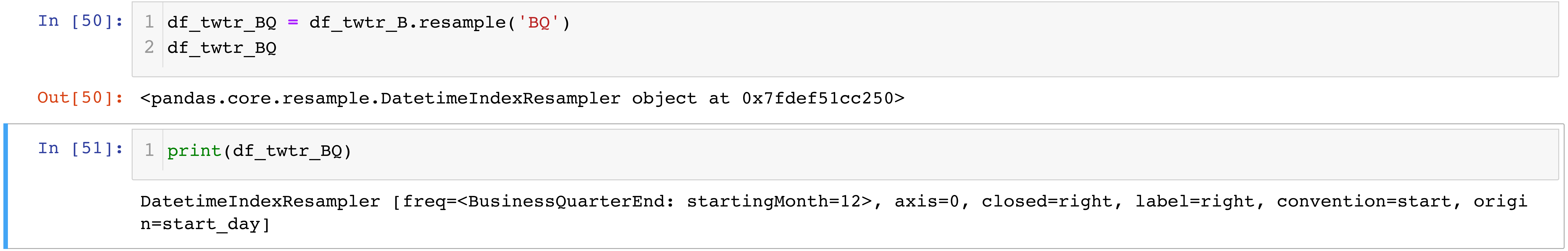
```
df_twtr_BQ = df_twtr_B.resample('BQ')
df_twtr_BQ
```

Out[50]:

```
<pandas.core.resample.DatetimeIndexResampler object at 0x7fdef51cc250>
```

Resampling: Downsampling

- Go from higher/shorter to lower/longer
- Need to aggregate (like groupby)
- Example: Downsampling from business day to business quarter



In [50]:
```
df_twtr_BQ = df_twtr_B.resample('BQ')
df_twtr_BQ
```

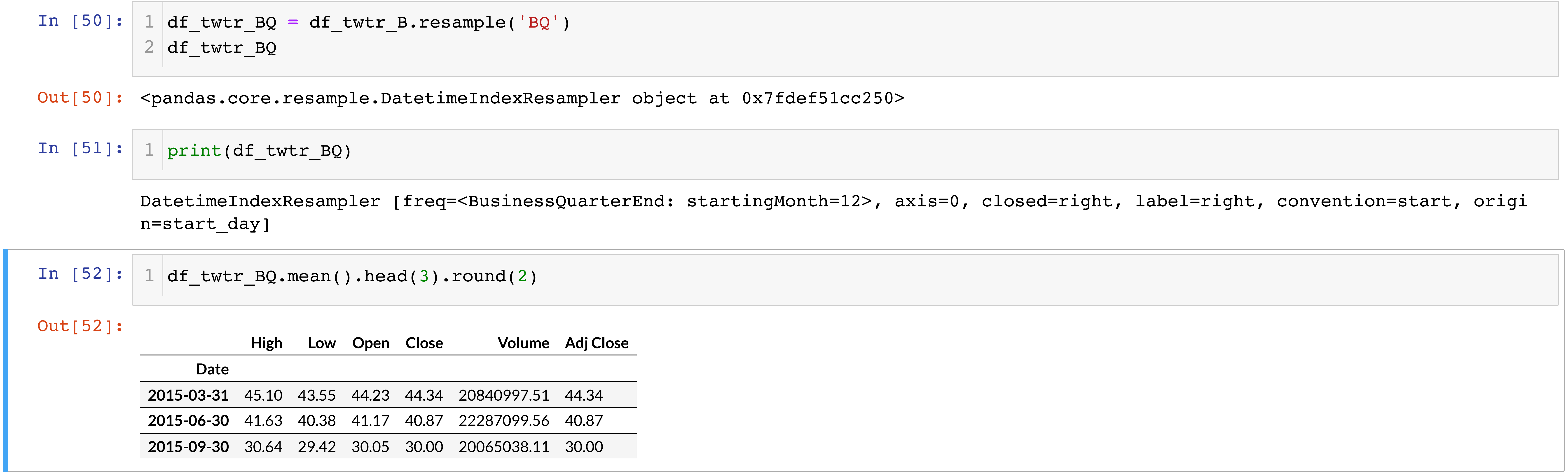
Out[50]:
```
<pandas.core.resample.DatetimeIndexResampler object at 0x7fdef51cc250>
```

In [51]:
```
print(df_twtr_BQ)
```

```
DatetimeIndexResampler [freq=<BusinessQuarterEnd: startingMonth=12>, axis=0, closed=right, label=right, convention=start, origi
n=start_day]
```

Resampling: Downsampling

- Go from higher/shorter to lower/longer
- Need to aggregate (like groupby)
- Example: Downsampling from business day to business quarter



In [50]:

```
df_twtr_BQ = df_twtr_B.resample('BQ')
df_twtr_BQ
```

Out[50]:

```
<pandas.core.resample.DatetimeIndexResampler object at 0x7fdef51cc250>
```

In [51]:

```
print(df_twtr_BQ)
```

```
DatetimeIndexResampler [freq=<BusinessQuarterEnd: startingMonth=12>, axis=0, closed=right, label=right, convention=start, origi
n=start_day]
```

In [52]:

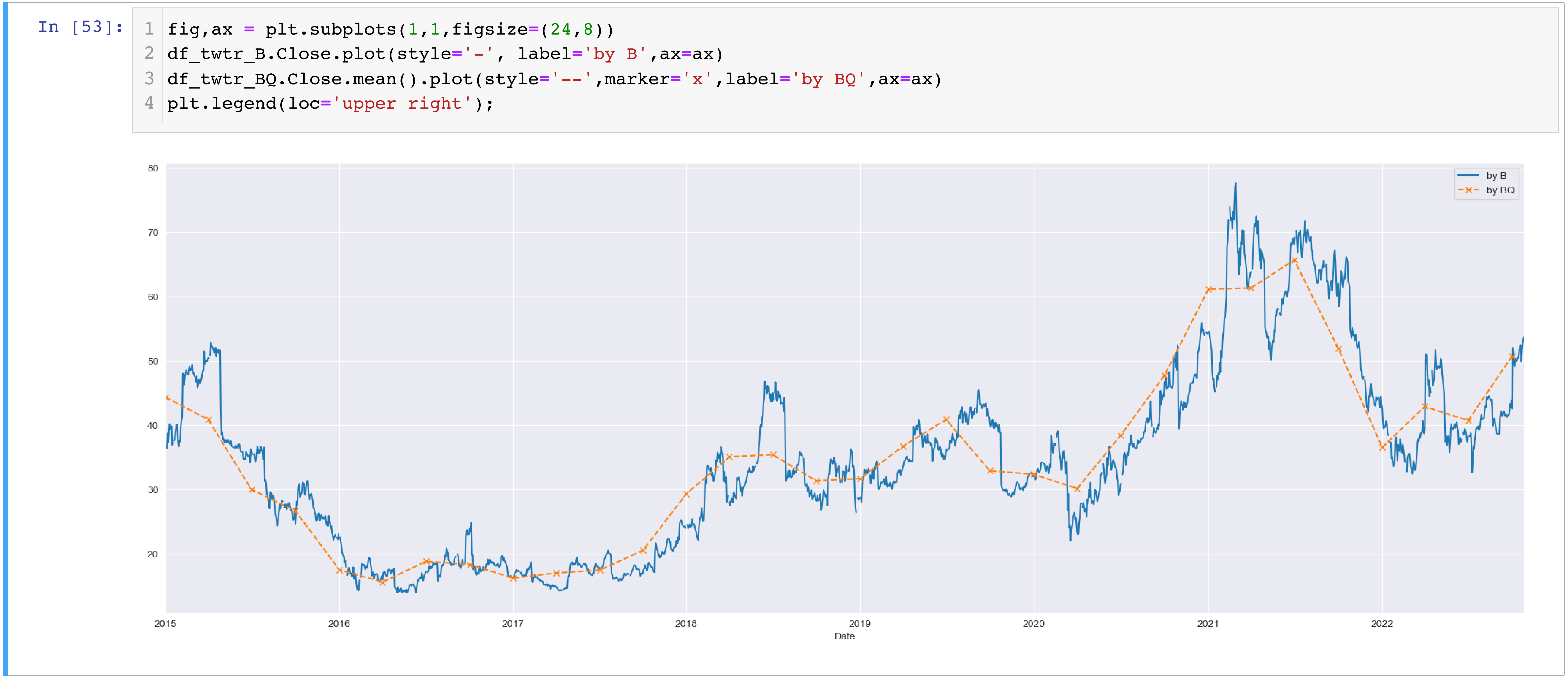
```
df_twtr_BQ.mean().head(3).round(2)
```

Out[52]:

	High	Low	Open	Close	Volume	Adj Close
Date						
2015-03-31	45.10	43.55	44.23	44.34	20840997.51	44.34
2015-06-30	41.63	40.38	41.17	40.87	22287099.56	40.87
2015-09-30	30.64	29.42	30.05	30.00	20065038.11	30.00

Resampling: Downsampling

Resampling: Downsampling



In [53]:

```python
fig,ax = plt.subplots(1,1,figsize=(24,8))
df_twtr_B.Close.plot(style='-', label='by B',ax=ax)
df_twtr_BQ.Close.mean().plot(style='--',marker='x',label='by BQ',ax=ax)
plt.legend(loc='upper right');
```

Resampling: Upsampling

- Go from lower/longer to higher/shorter
- Need to decide how to handle missing values
- Example: Upsample from business day to hour

Resampling: Upsampling

- Go from lower/longer to higher/shorter
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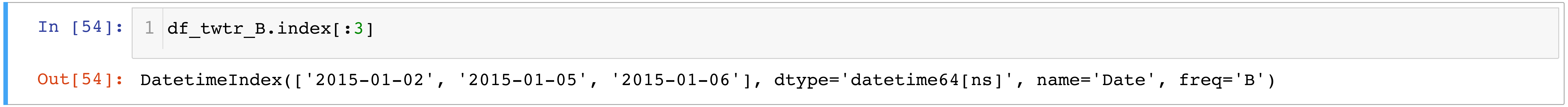
- Example: Upsample from business day to hour

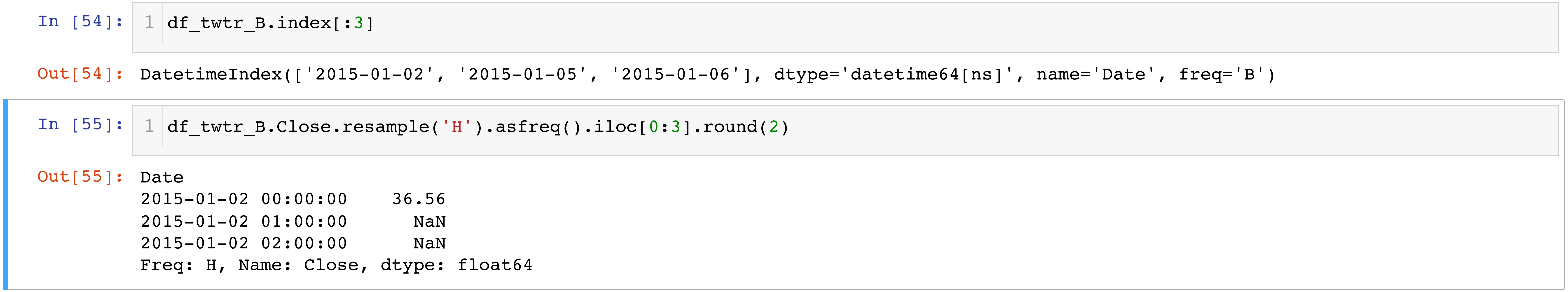


```
In [54]: df_twtr_B.index[:3]
```

```
Out[54]: DatetimeIndex(['2015-01-02', '2015-01-05', '2015-01-06'], dtype='datetime64[ns]', name='Date', freq='B')
```

Resampling: Upsampling

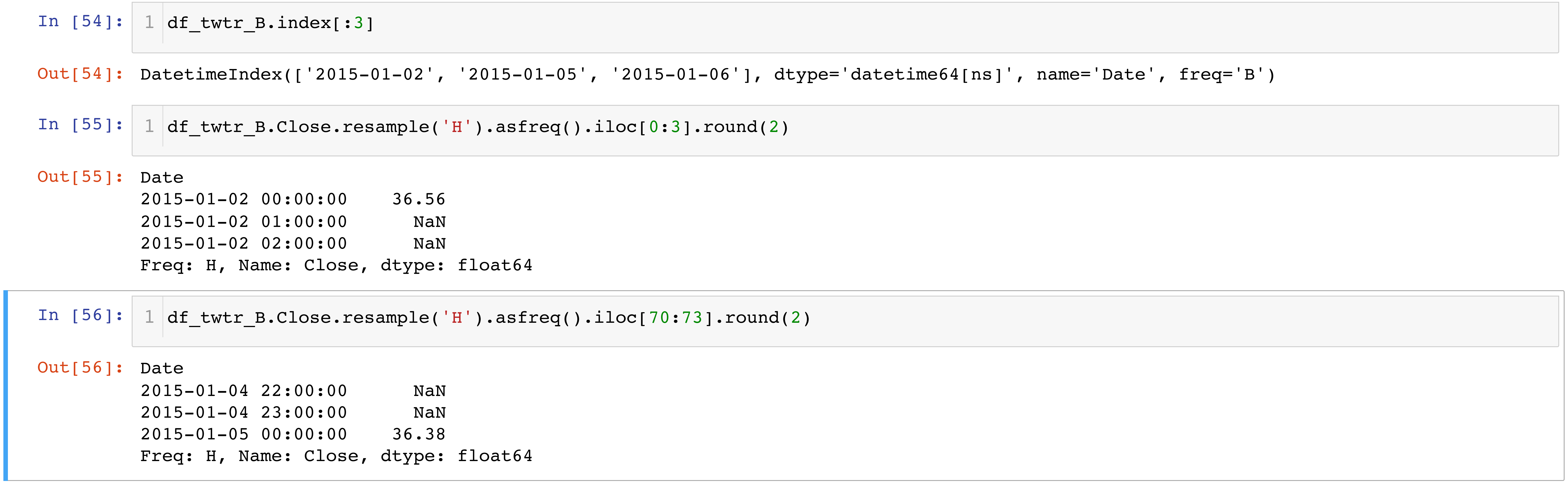
- Go from lower/longer to higher/shorter
- Need to decide how to handle missing values
- Example: Upsample from business day to hour



```
In [54]: df_twtr_B.index[:3]

Out[54]: DatetimeIndex(['2015-01-02', '2015-01-05', '2015-01-06'], dtype='datetime64[ns]', name='Date', freq='B')

In [55]: df_twtr_B.Close.resample('H').asfreq().iloc[0:3].round(2)

Out[55]: Date
         2015-01-02 00:00:00    36.56
         2015-01-02 01:00:00      NaN
         2015-01-02 02:00:00      NaN
         Freq: H, Name: Close, dtype: float64
```

Resampling: Upsampling

- Go from lower/longer to higher/shorter
- Need to decide how to handle missing values
- Example: Upsample from business day to hour



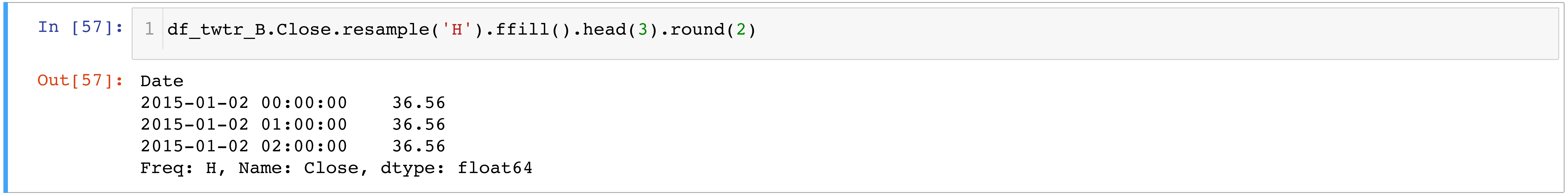
```
In [54]:  df_twtr_B.index[:3]

Out[54]:  DatetimeIndex(['2015-01-02', '2015-01-05', '2015-01-06'], dtype='datetime64[ns]', name='Date', freq='B')

In [55]:  df_twtr_B.Close.resample('H').asfreq().iloc[0:3].round(2)

Out[55]:  Date
          2015-01-02 00:00:00    36.56
          2015-01-02 01:00:00      NaN
          2015-01-02 02:00:00      NaN
          Freq: H, Name: Close, dtype: float64

In [56]:  df_twtr_B.Close.resample('H').asfreq().iloc[70:73].round(2)

Out[56]:  Date
          2015-01-04 22:00:00      NaN
          2015-01-04 23:00:00      NaN
          2015-01-05 00:00:00    36.38
          Freq: H, Name: Close, dtype: float64
```

Resampling: Upsampling

- `ffill()` : Forward Fill

Resampling: Upsampling

- `ffill()` : Forward Fill



In [57]:

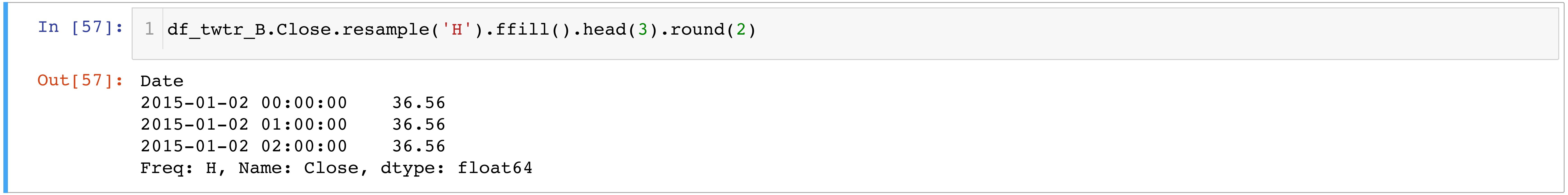
```
df_twtr_B.Close.resample('H').ffill().head(3).round(2)
```

Out[57]:

```
Date
2015-01-02 00:00:00    36.56
2015-01-02 01:00:00    36.56
2015-01-02 02:00:00    36.56
Freq: H, Name: Close, dtype: float64
```

Resampling: Upsampling

- `ffill()` : Forward Fill



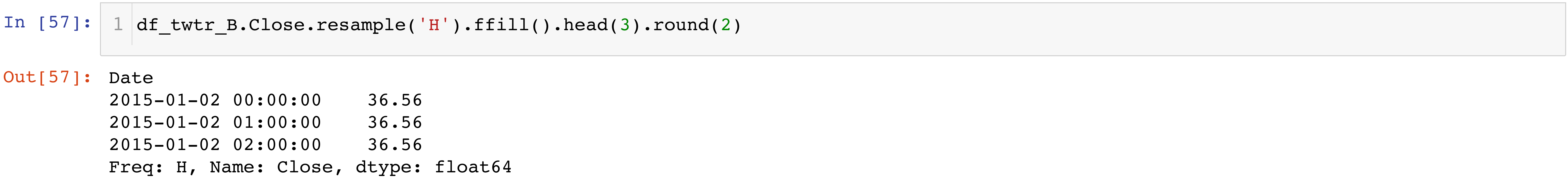
In [57]:
```
df_twtr_B.Close.resample('H').ffill().head(3).round(2)
```

Out[57]:
```
Date
2015-01-02 00:00:00    36.56
2015-01-02 01:00:00    36.56
2015-01-02 02:00:00    36.56
Freq: H, Name: Close, dtype: float64
```

- `bfill()`: Backward Fill

Resampling: Upsampling

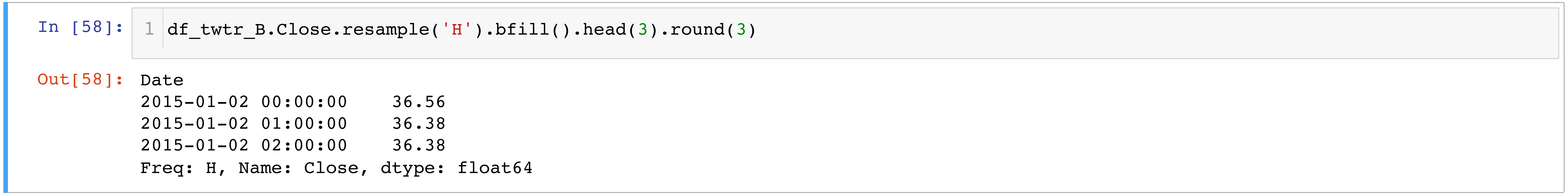
- `ffill()` : Forward Fill



```
In [57]: df_twtr_B.Close.resample('H').ffill().head(3).round(2)
```

```
Out[57]: Date
         2015-01-02 00:00:00    36.56
         2015-01-02 01:00:00    36.56
         2015-01-02 02:00:00    36.56
         Freq: H, Name: Close, dtype: float64
```

- `bfill()` : Backward Fill



```
In [58]: df_twtr_B.Close.resample('H').bfill().head(3).round(3)
```

```
Out[58]: Date
         2015-01-02 00:00:00    36.56
         2015-01-02 01:00:00    36.38
         2015-01-02 02:00:00    36.38
         Freq: H, Name: Close, dtype: float64
```

Moving/Rolling Windows

- Apply function on a fixed window moving across time
- Method of smoothing out the data
- **center** : place values at center of window

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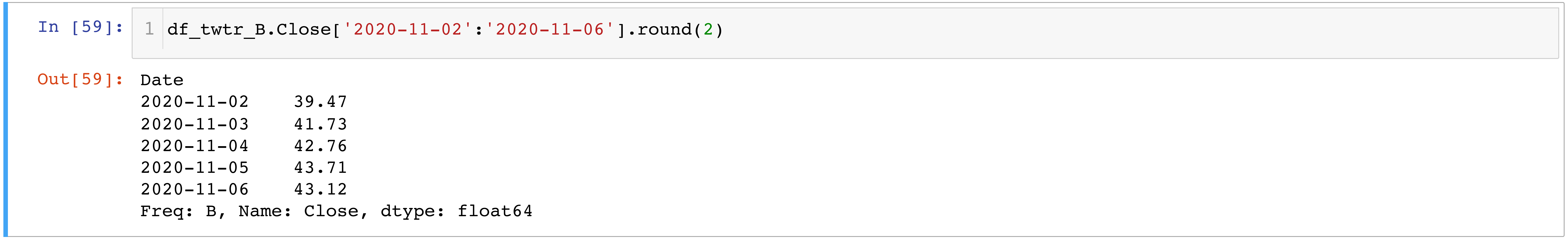
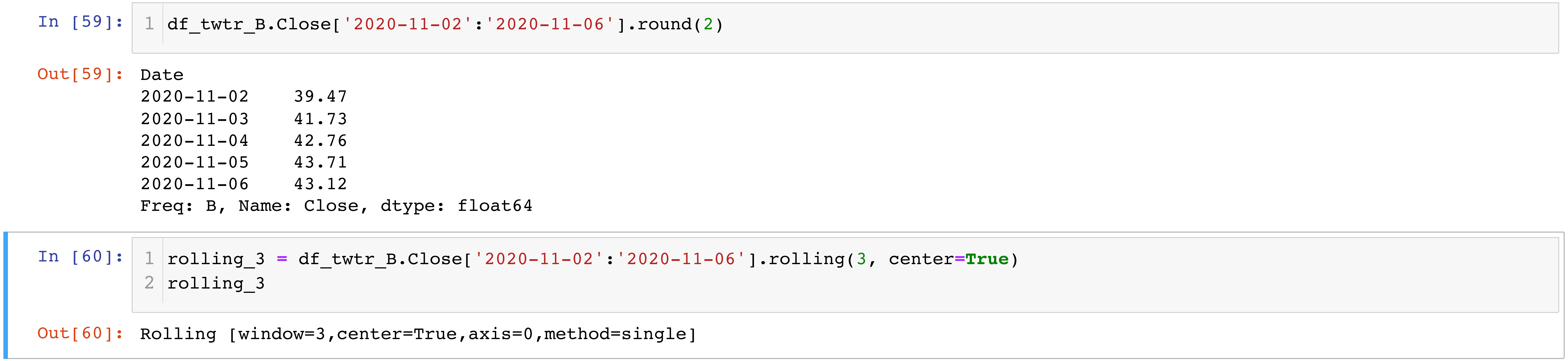


```
In [59]: df_twtr_B.Close['2020-11-02':'2020-11-06'].round(2)
```

```
Out[59]: Date
         2020-11-02    39.47
         2020-11-03    41.73
         2020-11-04    42.76
         2020-11-05    43.71
         2020-11-06    43.12
         Freq: B, Name: Close, dtype: float64
```

Moving/Rolling Windows

- Apply function on a fixed window moving across time
- Method of smoothing out the data
- **center** : place values at center of window

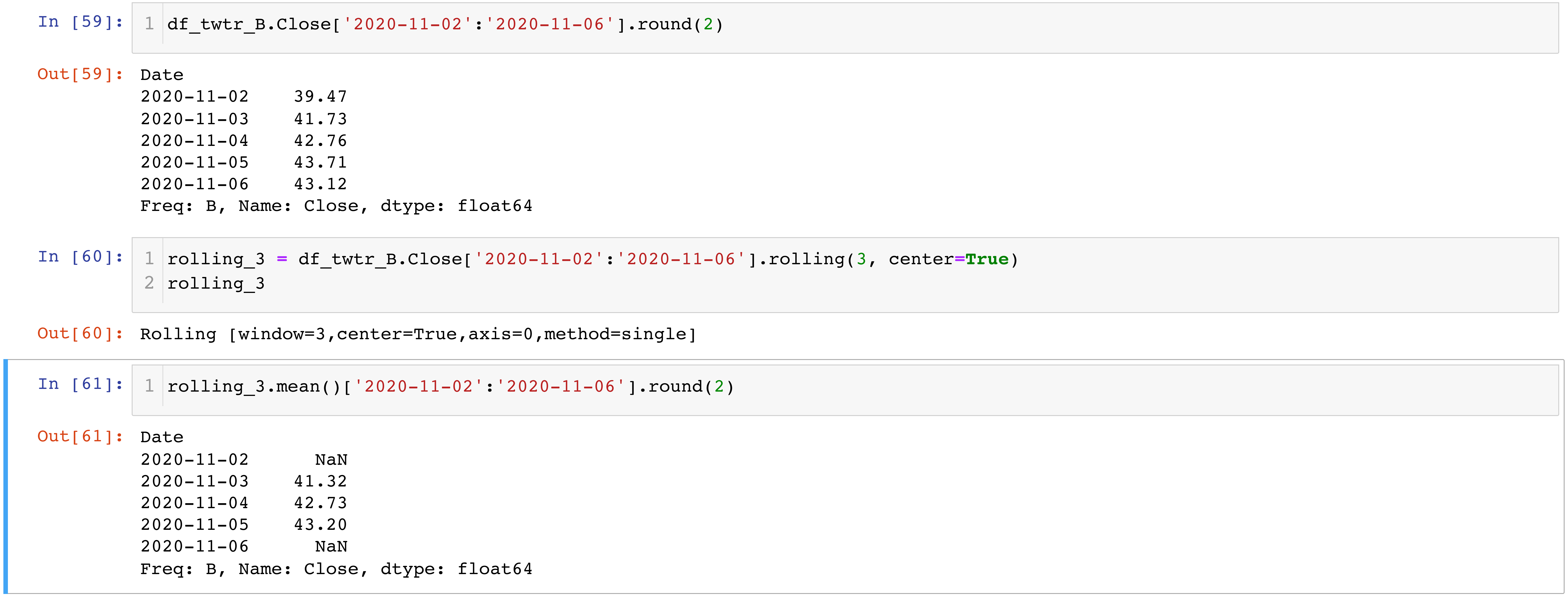


```
In [59]: df_twtr_B.Close['2020-11-02':'2020-11-06'].round(2)

Out[59]: Date
         2020-11-02    39.47
         2020-11-03    41.73
         2020-11-04    42.76
         2020-11-05    43.71
         2020-11-06    43.12
         Freq: B, Name: Close, dtype: float64
```

```
In [60]: rolling_3 = df_twtr_B.Close['2020-11-02':'2020-11-06'].rolling(3, center=True)
         rolling_3

Out[60]: Rolling [window=3,center=True,axis=0,method=single]
```

Moving/Rolling Windows

- Apply function on a fixed window moving across time
- Method of smoothing out the data
- **center** : place values at center of window



```
In [59]: df_twtr_B.Close['2020-11-02':'2020-11-06'].round(2)
```

```
Out[59]: Date
         2020-11-02    39.47
         2020-11-03    41.73
         2020-11-04    42.76
         2020-11-05    43.71
         2020-11-06    43.12
         Freq: B, Name: Close, dtype: float64
```

```
In [60]: rolling_3 = df_twtr_B.Close['2020-11-02':'2020-11-06'].rolling(3, center=True)
         rolling_3
```

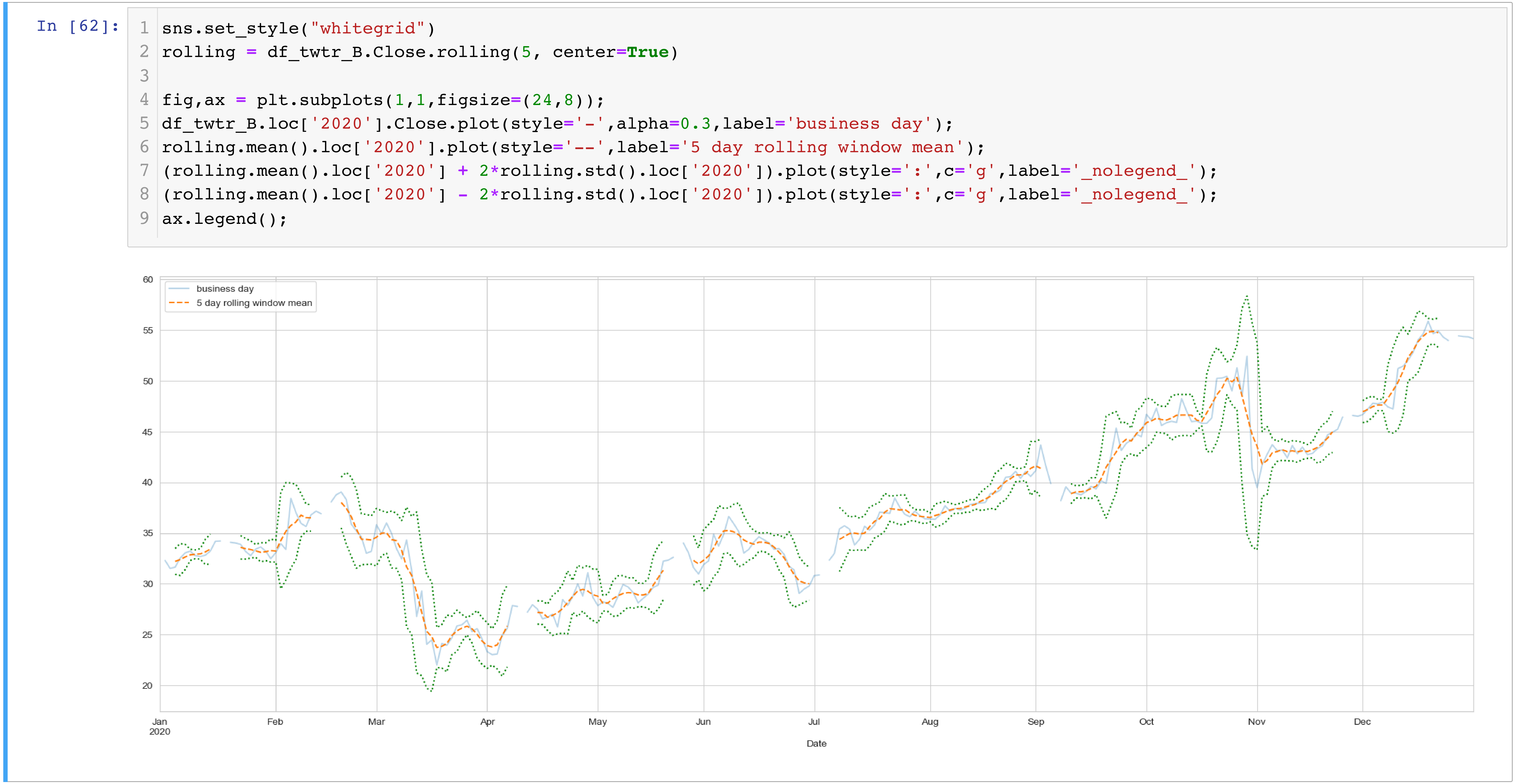
```
Out[60]: Rolling [window=3,center=True,axis=0,method=single]
```

```
In [61]: rolling_3.mean()['2020-11-02':'2020-11-06'].round(2)
```

```
Out[61]: Date
         2020-11-02      NaN
         2020-11-03    41.32
         2020-11-04    42.73
         2020-11-05    43.20
         2020-11-06      NaN
         Freq: B, Name: Close, dtype: float64
```

Moving Windows

Moving Windows



In [62]:

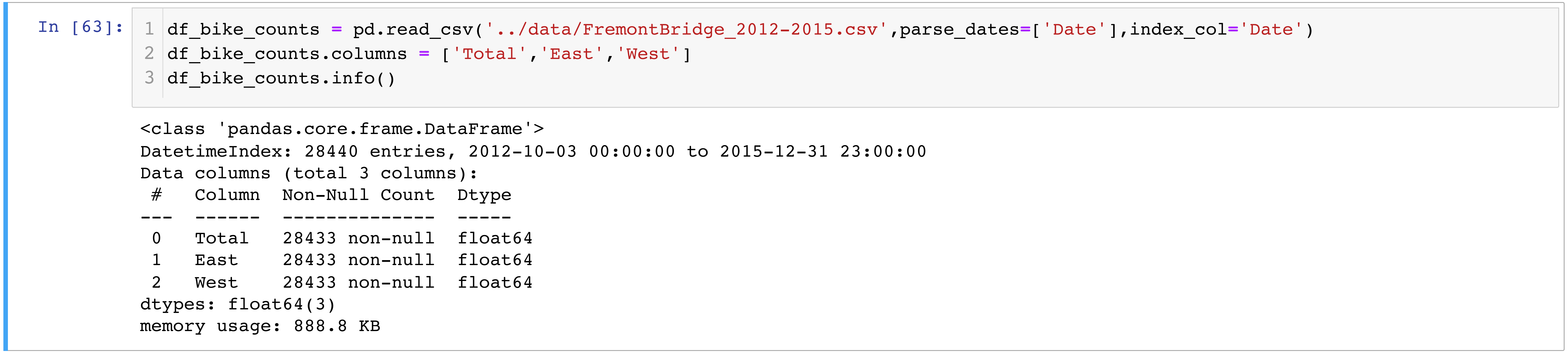
```python
sns.set_style("whitegrid")
rolling = df_twtr_B.Close.rolling(5, center=True)

fig,ax = plt.subplots(1,1,figsize=(24,8));
df_twtr_B.loc['2020'].Close.plot(style='-',alpha=0.3,label='business day');
rolling.mean().loc['2020'].plot(style='--',label='5 day rolling window mean');
(rolling.mean().loc['2020'] + 2*rolling.std().loc['2020']).plot(style=':',c='g',label='_nolegend_');
(rolling.mean().loc['2020'] - 2*rolling.std().loc['2020']).plot(style=':',c='g',label='_nolegend_');
ax.legend();
```

Example: Bike Travel (From PDSH Chapter 3.11)

- Bicycle traffic over Fremont Bridge in Seattle in 2012
- Data gathered using: `!curl -o ../data/FremontBridge.csv https://data.seattle.gov/api/views/65db-xm6k/rows.csv?accessType=DOWNLOAD`

Example: Bike Travel (From PDSH Chapter 3.11)

- Bicycle traffic over Fremont Bridge in Seattle in 2012
- Data gathered using: `!curl -o ../data/FremontBridge.csv https://data.seattle.gov/api/views/65db-xm6k/rows.csv?accessType=DOWNLOAD`



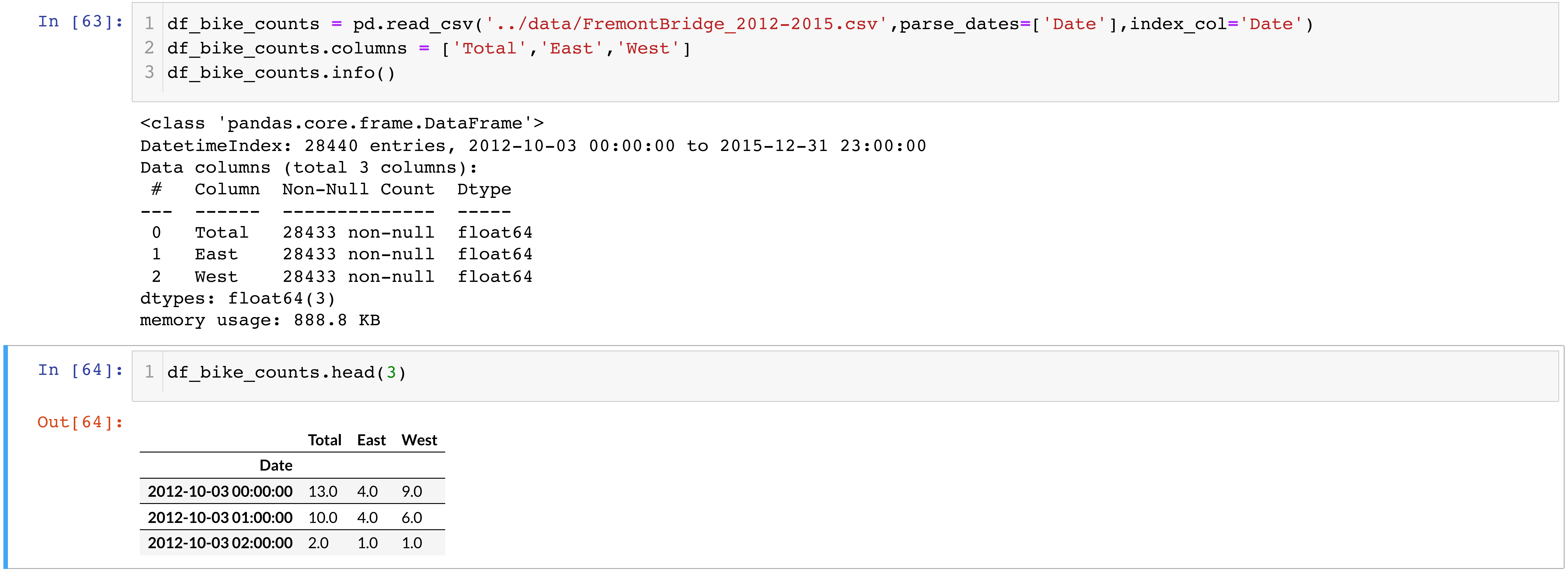
In [63]:

```
df_bike_counts = pd.read_csv('../data/FremontBridge_2012-2015.csv',parse_dates=['Date'],index_col='Date')
df_bike_counts.columns = ['Total','East','West']
df_bike_counts.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 28440 entries, 2012-10-03 00:00:00 to 2015-12-31 23:00:00
Data columns (total 3 columns):
 #   Column  Non-Null Count  Dtype  
---  ------  --------------  -----  
 0   Total   28433 non-null  float64
 1   East    28433 non-null  float64
 2   West    28433 non-null  float64
dtypes: float64(3)
memory usage: 888.8 KB
```

Example: Bike Travel (From PDSH Chapter 3.11)

- Bicycle traffic over Fremont Bridge in Seattle in 2012
- Data gathered using: `!curl -o ../data/FremontBridge.csv https://data.seattle.gov/api/views/65db-xm6k/rows.csv?accessType=DOWNLOAD`



In [63]:

```
df_bike_counts = pd.read_csv('../data/FremontBridge_2012-2015.csv',parse_dates=['Date'],index_col='Date')
df_bike_counts.columns = ['Total','East','West']
df_bike_counts.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 28440 entries, 2012-10-03 00:00:00 to 2015-12-31 23:00:00
Data columns (total 3 columns):
 #   Column  Non-Null Count  Dtype  
---  ------  --------------  -----  
 0   Total   28433 non-null  float64
 1   East    28433 non-null  float64
 2   West    28433 non-null  float64
dtypes: float64(3)
memory usage: 888.8 KB
```

In [64]:

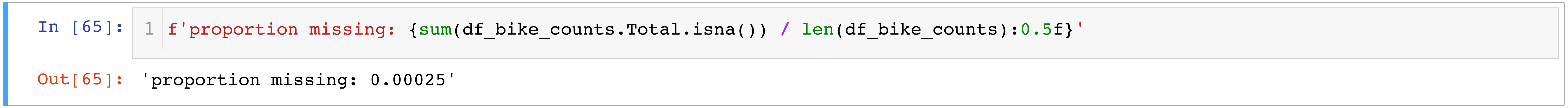
```
df_bike_counts.head(3)
```

Out[64]:

	Total	East	West
Date			
2012-10-03 00:00:00	13.0	4.0	9.0
2012-10-03 01:00:00	10.0	4.0	6.0
2012-10-03 02:00:00	2.0	1.0	1.0

Example: Fill Missing Values

Example: Fill Missing Values



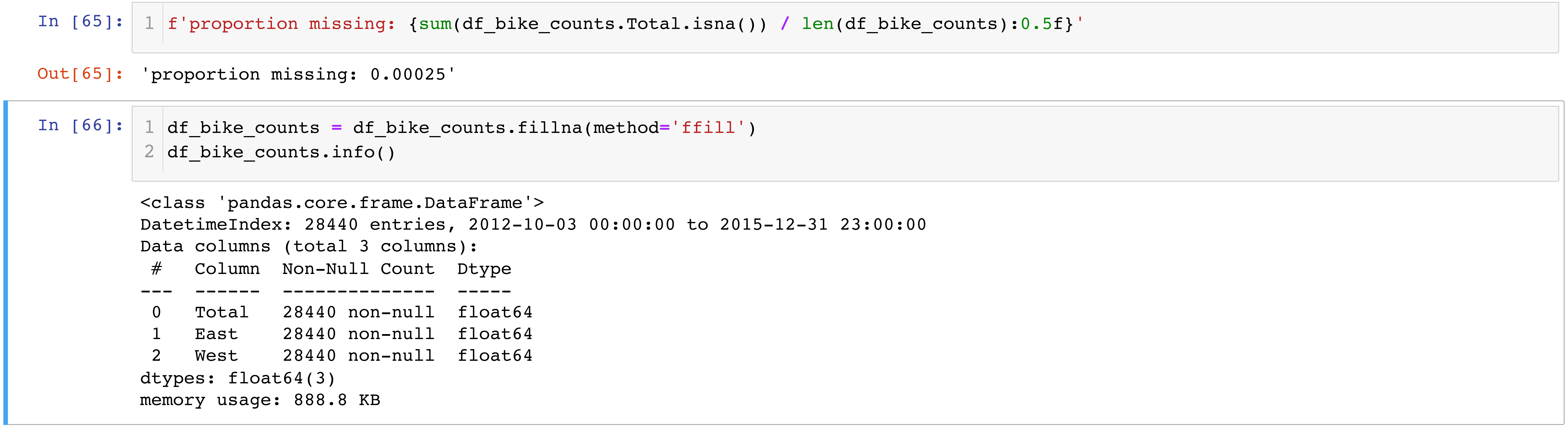
In [65]:

```
f'proportion missing: {sum(df_bike_counts.Total.isna()) / len(df_bike_counts):0.5f}'
```

Out[65]:

```
'proportion missing: 0.00025'
```

Example: Fill Missing Values



In [65]:

```python
f'proportion missing: {sum(df_bike_counts.Total.isna()) / len(df_bike_counts):0.5f}'
```

Out[65]:

```
'proportion missing: 0.00025'
```

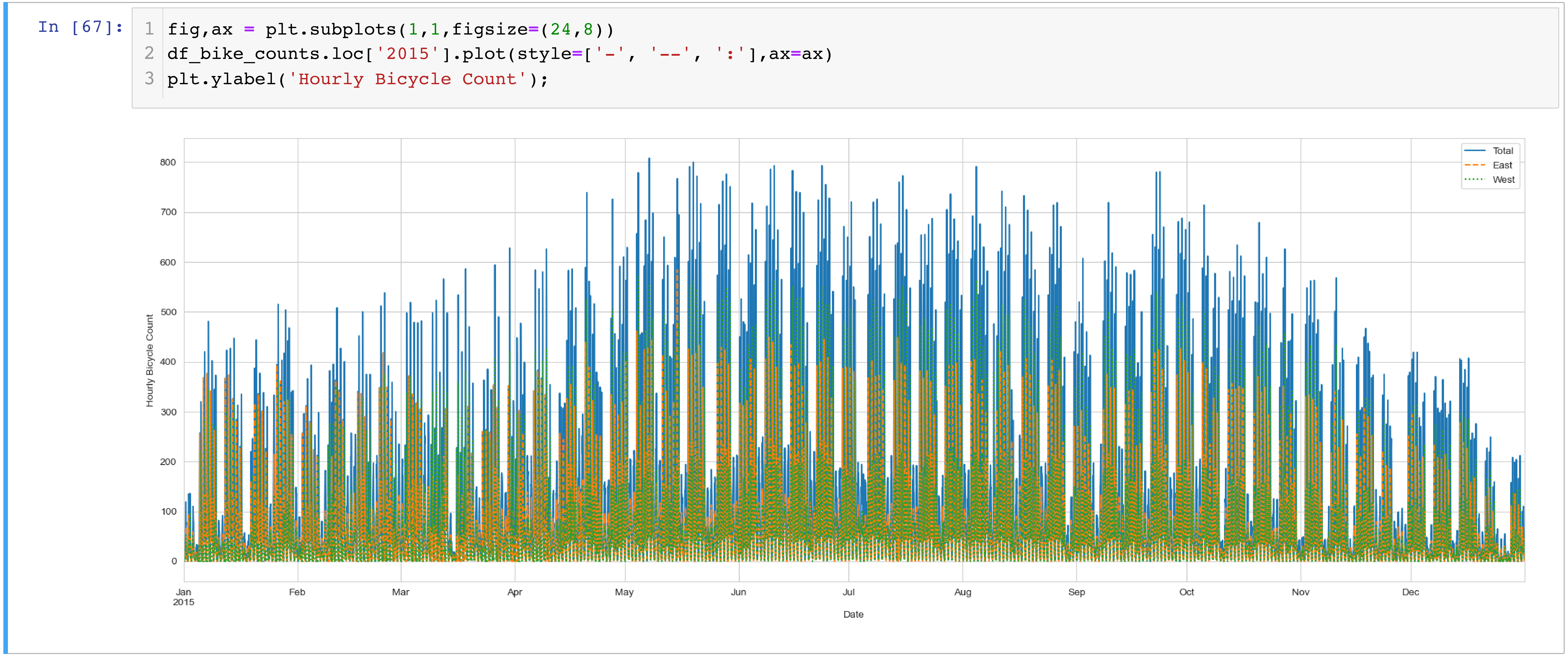
In [66]:

```python
df_bike_counts = df_bike_counts.fillna(method='ffill')
df_bike_counts.info()
```

```
<class 'pandas.core.frame.DataFrame'>
DatetimeIndex: 28440 entries, 2012-10-03 00:00:00 to 2015-12-31 23:00:00
Data columns (total 3 columns):
 #   Column  Non-Null Count  Dtype  
---  ------  --------------  -----  
 0   Total   28440 non-null  float64
 1   East    28440 non-null  float64
 2   West    28440 non-null  float64
dtypes: float64(3)
memory usage: 888.8 KB
```

Plot data from 2015

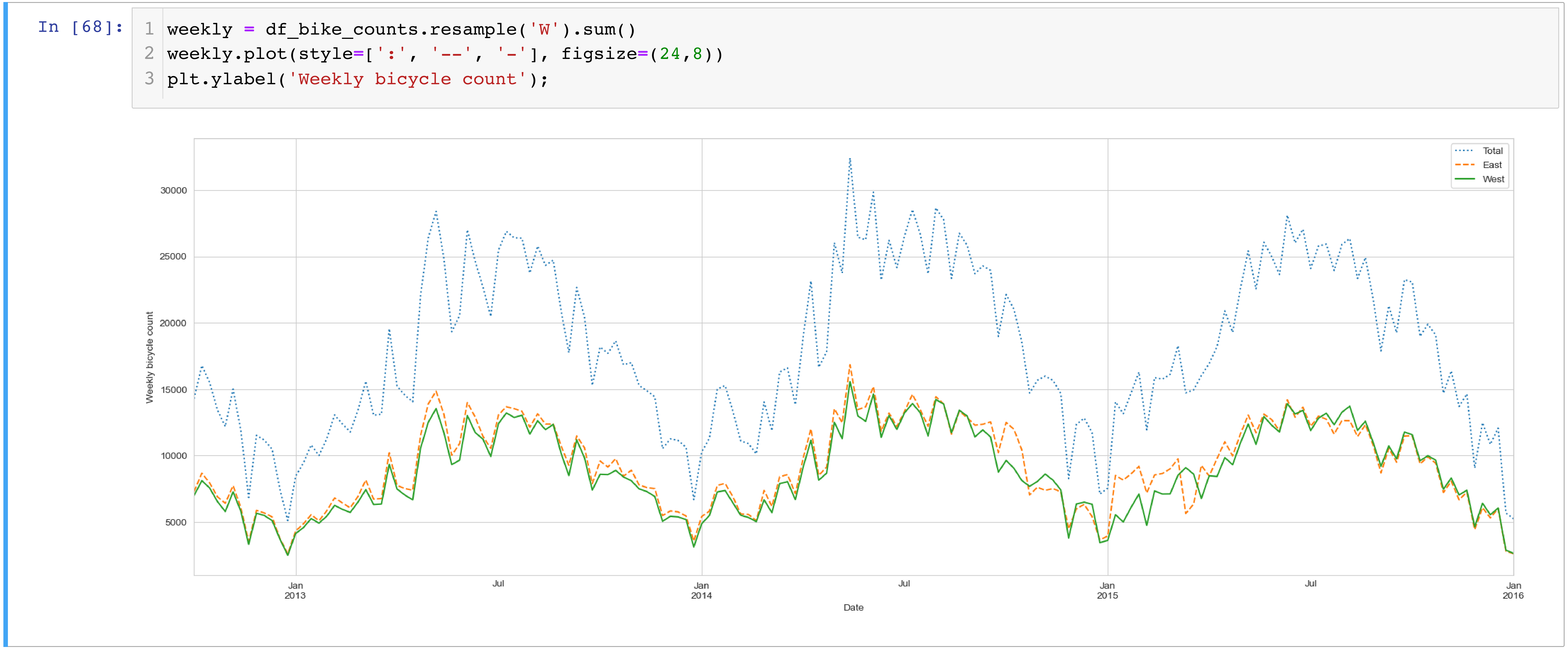
Plot data from 2015



```
fig,ax = plt.subplots(1,1,figsize=(24,8))
df_bike_counts.loc['2015'].plot(style=['-', '--', ':'],ax=ax)
plt.ylabel('Hourly Bicycle Count');
```

Downsample to weekly sum to smooth things out

Downsample to weekly sum to smooth things out

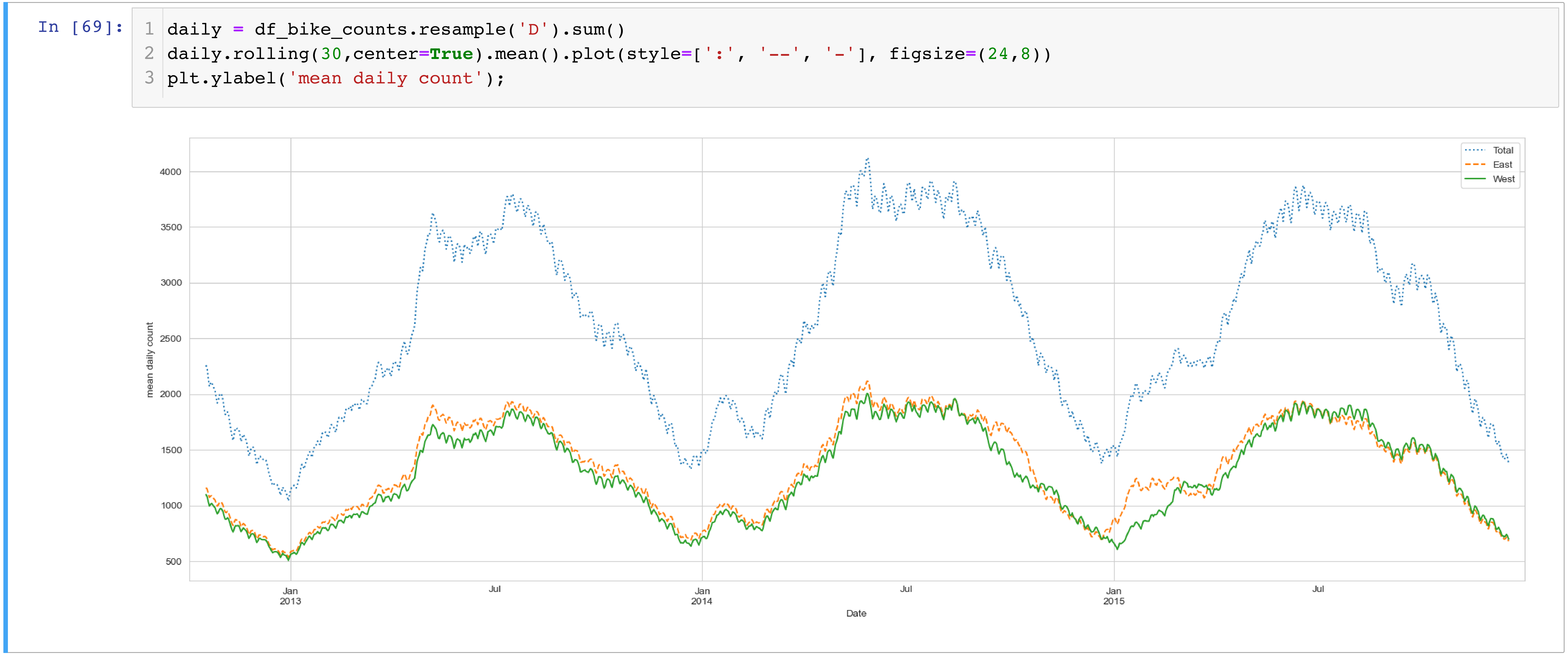


In [68]:

```python
weekly = df_bike_counts.resample('W').sum()
weekly.plot(style=[':', '--', '-'], figsize=(24,8))
plt.ylabel('Weekly bicycle count');
```

Resample at daily for a more granular view and apply a rolling window of 30 days

Resample at daily for a more granular view and apply a rolling window of 30 days

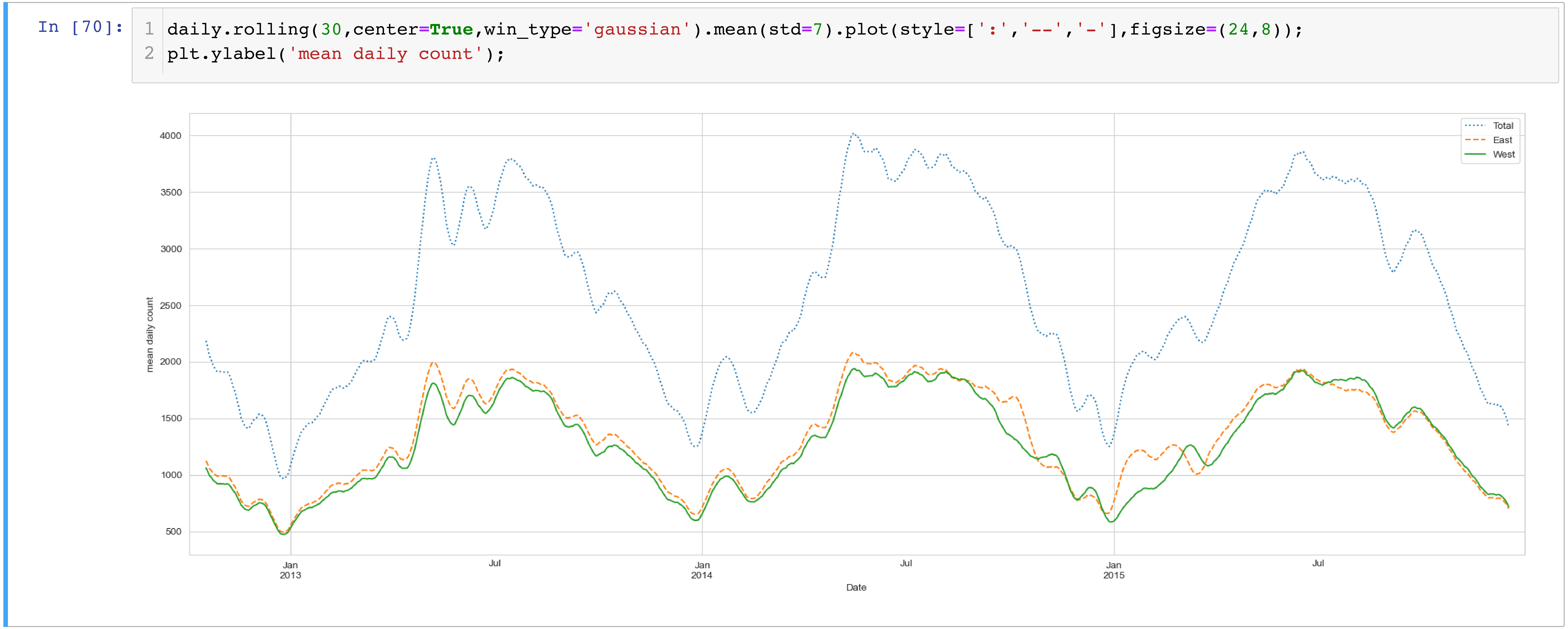


In [69]:

```
daily = df_bike_counts.resample('D').sum()
daily.rolling(30,center=True).mean().plot(style=[':', '--', '-'], figsize=(24,8))
plt.ylabel('mean daily count');
```

A wider window using a gaussian filter smooths more while accentuating daily differences

A wider window using a gaussian filter smooths more while accentuating daily differences

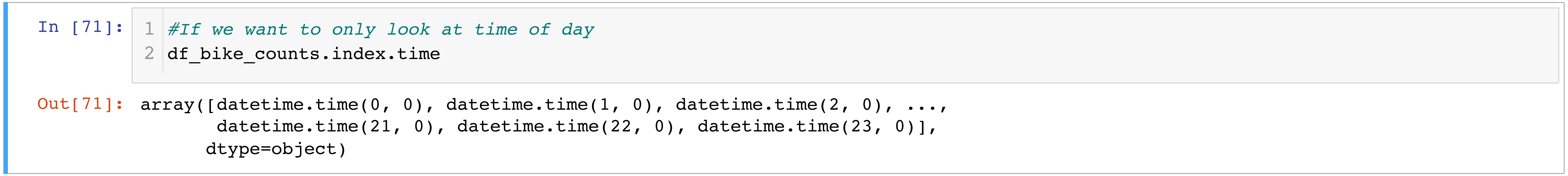


In [70]:

```
daily.rolling(30,center=True,win_type='gaussian').mean(std=7).plot(style=[':','--','-'],figsize=(24,8));
plt.ylabel('mean daily count');
```

From Datetime to Time

From Datetime to Time



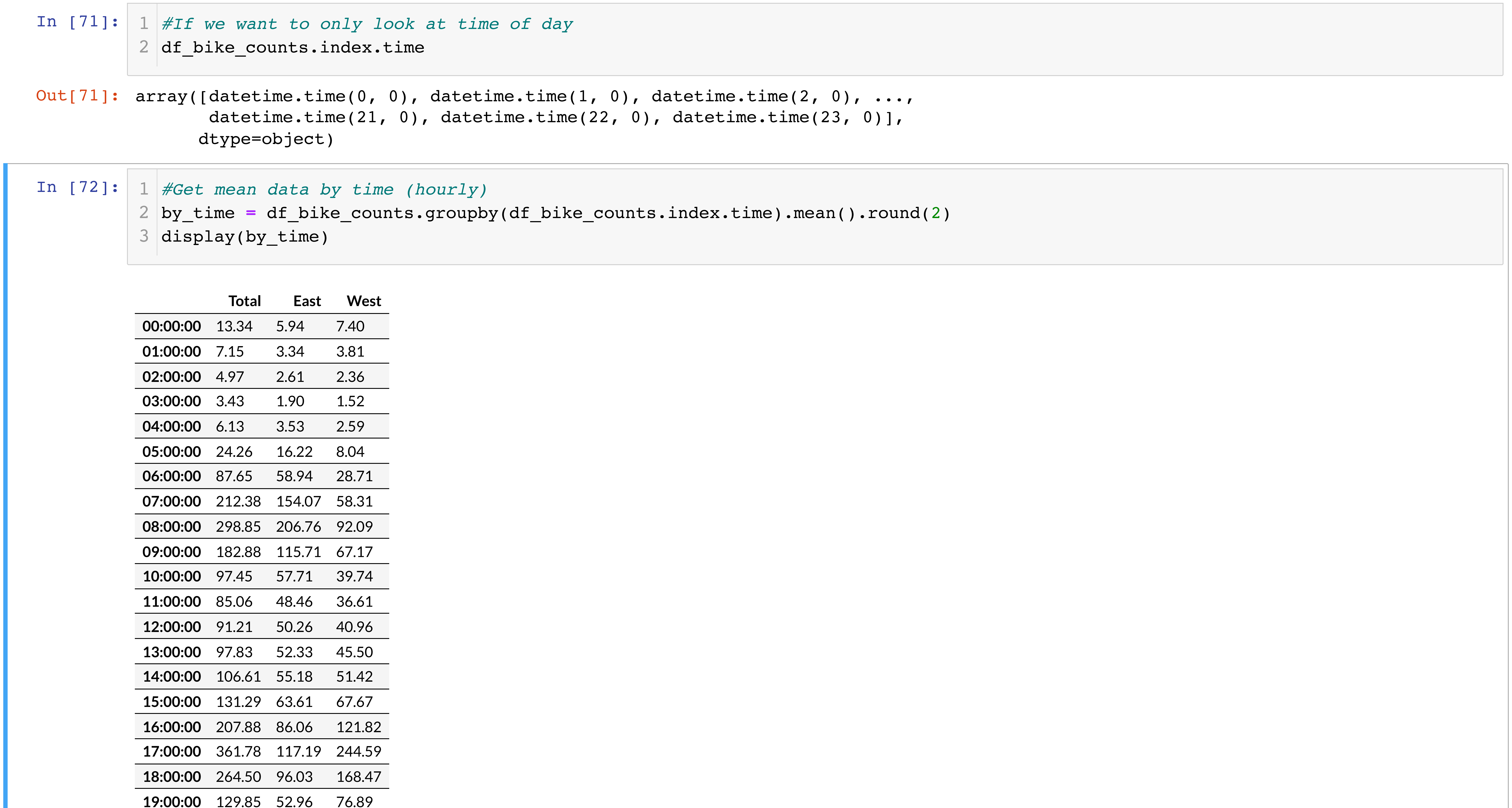
In [71]:

```
#If we want to only look at time of day
df_bike_counts.index.time
```

Out[71]:

```
array([datetime.time(0, 0), datetime.time(1, 0), datetime.time(2, 0), ...,
       datetime.time(21, 0), datetime.time(22, 0), datetime.time(23, 0)],
      dtype=object)
```

From Datetime to Time



In [71]:

```
#If we want to only look at time of day
df_bike_counts.index.time
```

Out[71]:

```
array([datetime.time(0, 0), datetime.time(1, 0), datetime.time(2, 0), ...,
       datetime.time(21, 0), datetime.time(22, 0), datetime.time(23, 0)],
      dtype=object)
```

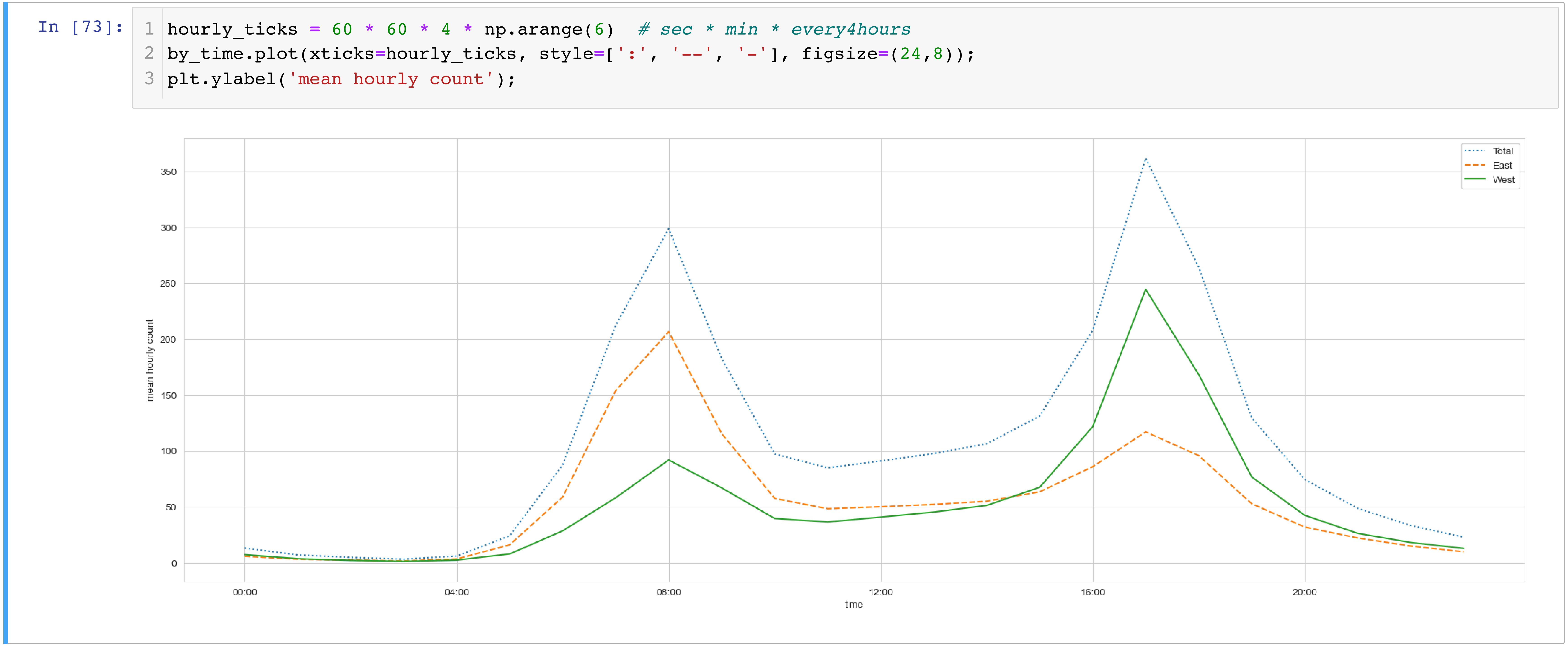
In [72]:

```
#Get mean data by time (hourly)
by_time = df_bike_counts.groupby(df_bike_counts.index.time).mean().round(2)
display(by_time)
```

	Total	East	West
00:00:00	13.34	5.94	7.40
01:00:00	7.15	3.34	3.81
02:00:00	4.97	2.61	2.36
03:00:00	3.43	1.90	1.52
04:00:00	6.13	3.53	2.59
05:00:00	24.26	16.22	8.04
06:00:00	87.65	58.94	28.71
07:00:00	212.38	154.07	58.31
08:00:00	298.85	206.76	92.09
09:00:00	182.88	115.71	67.17
10:00:00	97.45	57.71	39.74
11:00:00	85.06	48.46	36.61
12:00:00	91.21	50.26	40.96
13:00:00	97.83	52.33	45.50
14:00:00	106.61	55.18	51.42
15:00:00	131.29	63.61	67.67
16:00:00	207.88	86.06	121.82
17:00:00	361.78	117.19	244.59
18:00:00	264.50	96.03	168.47
19:00:00	129.85	52.96	76.89

Plot by hour of the day

Plot by hour of the day

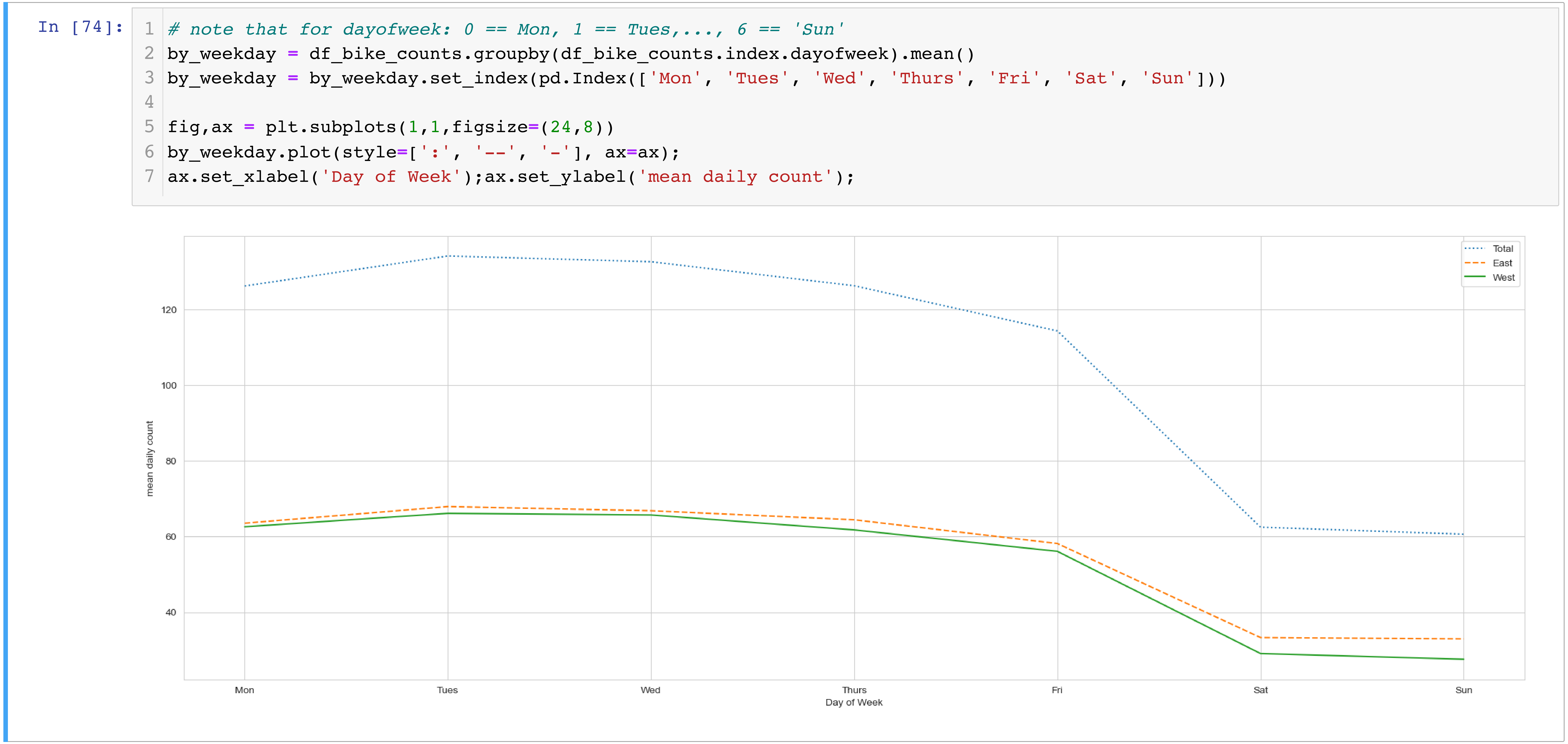


In [73]:

```python
hourly_ticks = 60 * 60 * 4 * np.arange(6)  # sec * min * every4hours
by_time.plot(xticks=hourly_ticks, style=[':', '--', '-'], figsize=(24,8));
plt.ylabel('mean hourly count');
```

Can also look at average by day of week

Can also look at average by day of week

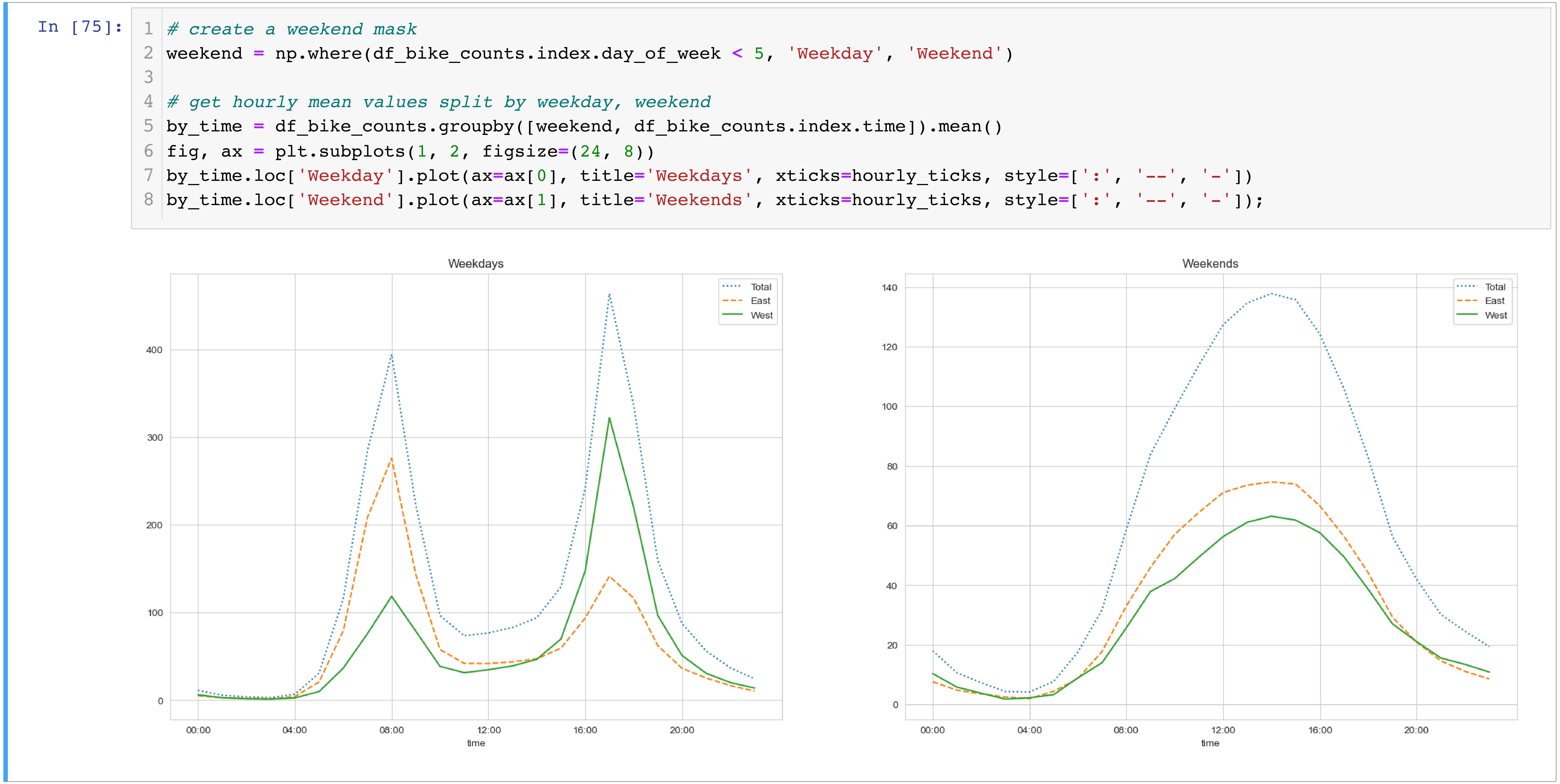


In [74]:

```
# note that for dayofweek: 0 == Mon, 1 == Tues,..., 6 == 'Sun'
by_weekday = df_bike_counts.groupby(df_bike_counts.index.dayofweek).mean()
by_weekday = by_weekday.set_index(pd.Index(['Mon', 'Tues', 'Wed', 'Thurs', 'Fri', 'Sat', 'Sun']))

fig,ax = plt.subplots(1,1,figsize=(24,8))
by_weekday.plot(style=[':', '--', '-'], ax=ax);
ax.set_xlabel('Day of Week');ax.set_ylabel('mean daily count');
```

Separate out weekdays and weekends

Separate out weekdays and weekends

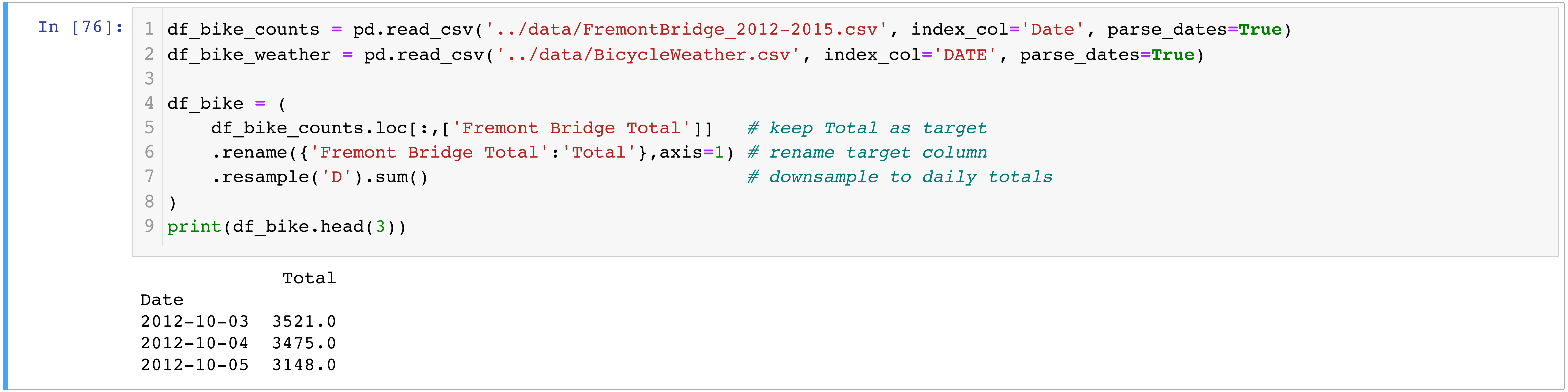


In [75]:

```python
# create a weekend mask
weekend = np.where(df_bike_counts.index.day_of_week < 5, 'Weekday', 'Weekend')

# get hourly mean values split by weekday, weekend
by_time = df_bike_counts.groupby([weekend, df_bike_counts.index.time]).mean()
fig, ax = plt.subplots(1, 2, figsize=(24, 8))
by_time.loc['Weekday'].plot(ax=ax[0], title='Weekdays', xticks=hourly_ticks, style=[':', '--', '-'])
by_time.loc['Weekend'].plot(ax=ax[1], title='Weekends', xticks=hourly_ticks, style=[':', '--', '-']);
```

Can we predict daily Total bike traffic?

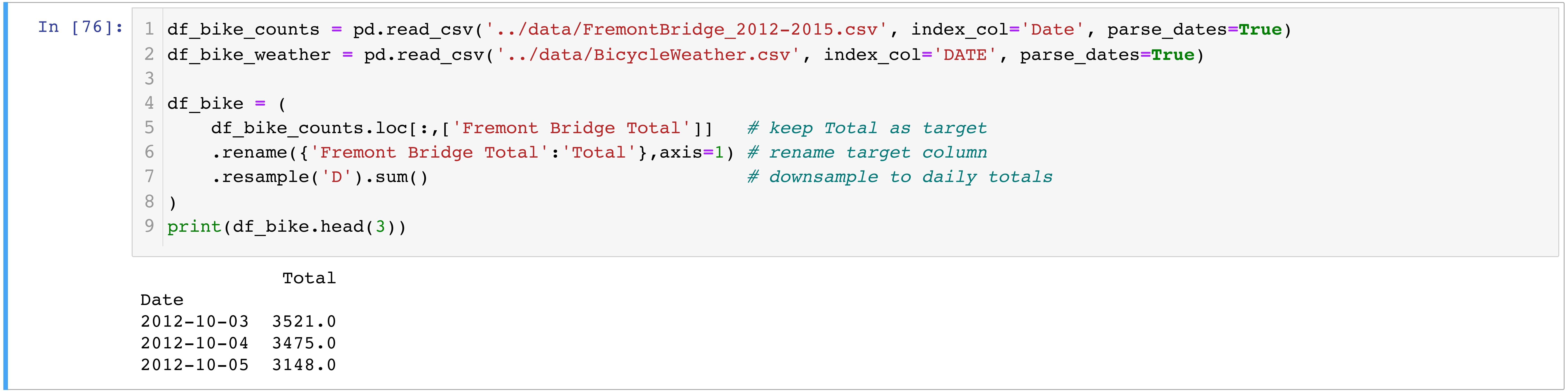
Can we predict daily Total bike traffic?



```python
df_bike_counts = pd.read_csv('../data/FremontBridge_2012-2015.csv', index_col='Date', parse_dates=True)
df_bike_weather = pd.read_csv('../data/BicycleWeather.csv', index_col='DATE', parse_dates=True)

df_bike = (
    df_bike_counts.loc[:,['Fremont Bridge Total']]   # keep Total as target
    .rename({'Fremont Bridge Total':'Total'},axis=1) # rename target column
    .resample('D').sum()                             # downsample to daily totals
)
print(df_bike.head(3))
```

```
             Total
Date
2012-10-03  3521.0
2012-10-04  3475.0
2012-10-05  3148.0
```

Can we predict daily Total bike traffic?



In [76]:

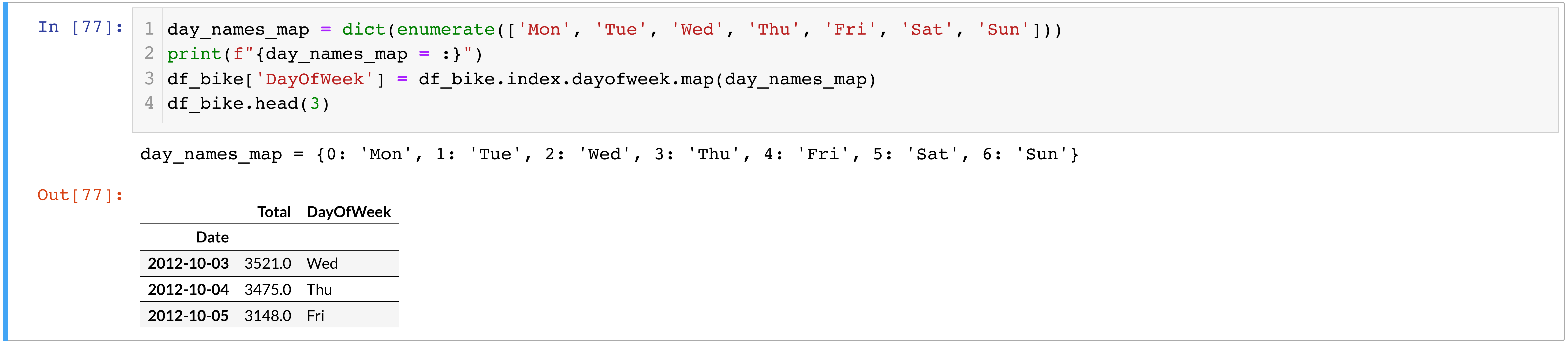
```python
df_bike_counts = pd.read_csv('../data/FremontBridge_2012-2015.csv', index_col='Date', parse_dates=True)
df_bike_weather = pd.read_csv('../data/BicycleWeather.csv', index_col='DATE', parse_dates=True)

df_bike = (
    df_bike_counts.loc[:,['Fremont Bridge Total']]   # keep Total as target
    .rename({'Fremont Bridge Total':'Total'},axis=1) # rename target column
    .resample('D').sum()                             # downsample to daily totals
)
print(df_bike.head(3))
```

```
             Total
Date
2012-10-03  3521.0
2012-10-04  3475.0
2012-10-05  3148.0
```

On to Feature Engineering…

Add ’day of week’

Add ’day of week’



In [77]:

```
day_names_map = dict(enumerate(['Mon', 'Tue', 'Wed', 'Thu', 'Fri', 'Sat', 'Sun']))
print(f"{day_names_map = :}")
df_bike['DayOfWeek'] = df_bike.index.dayofweek.map(day_names_map)
df_bike.head(3)
```

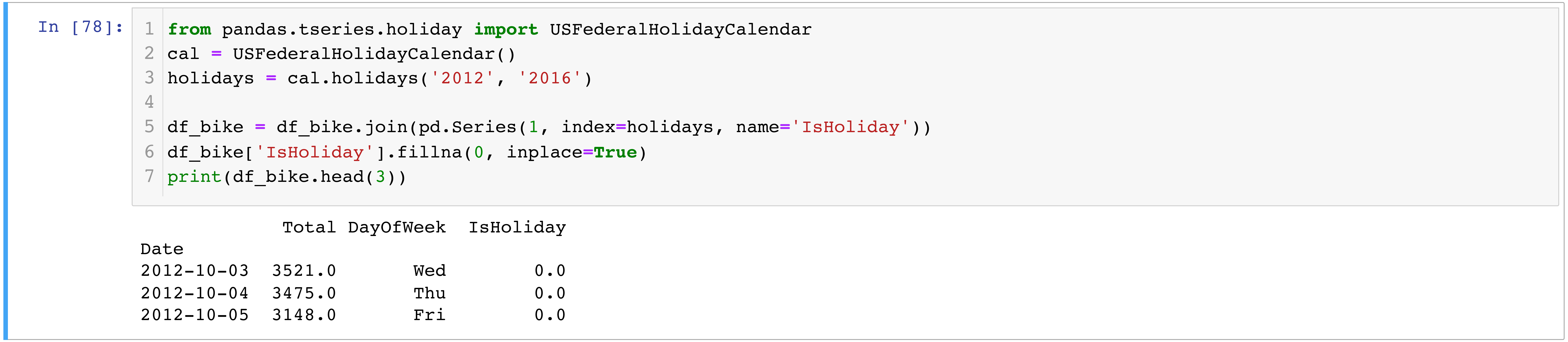
```
day_names_map = {0: 'Mon', 1: 'Tue', 2: 'Wed', 3: 'Thu', 4: 'Fri', 5: 'Sat', 6: 'Sun'}
```

Out[77]:

	Total	DayOfWeek
Date		
2012-10-03	3521.0	Wed
2012-10-04	3475.0	Thu
2012-10-05	3148.0	Fri

Add ’is it a holiday’ dummy feature

Add 'is it a holiday' dummy feature

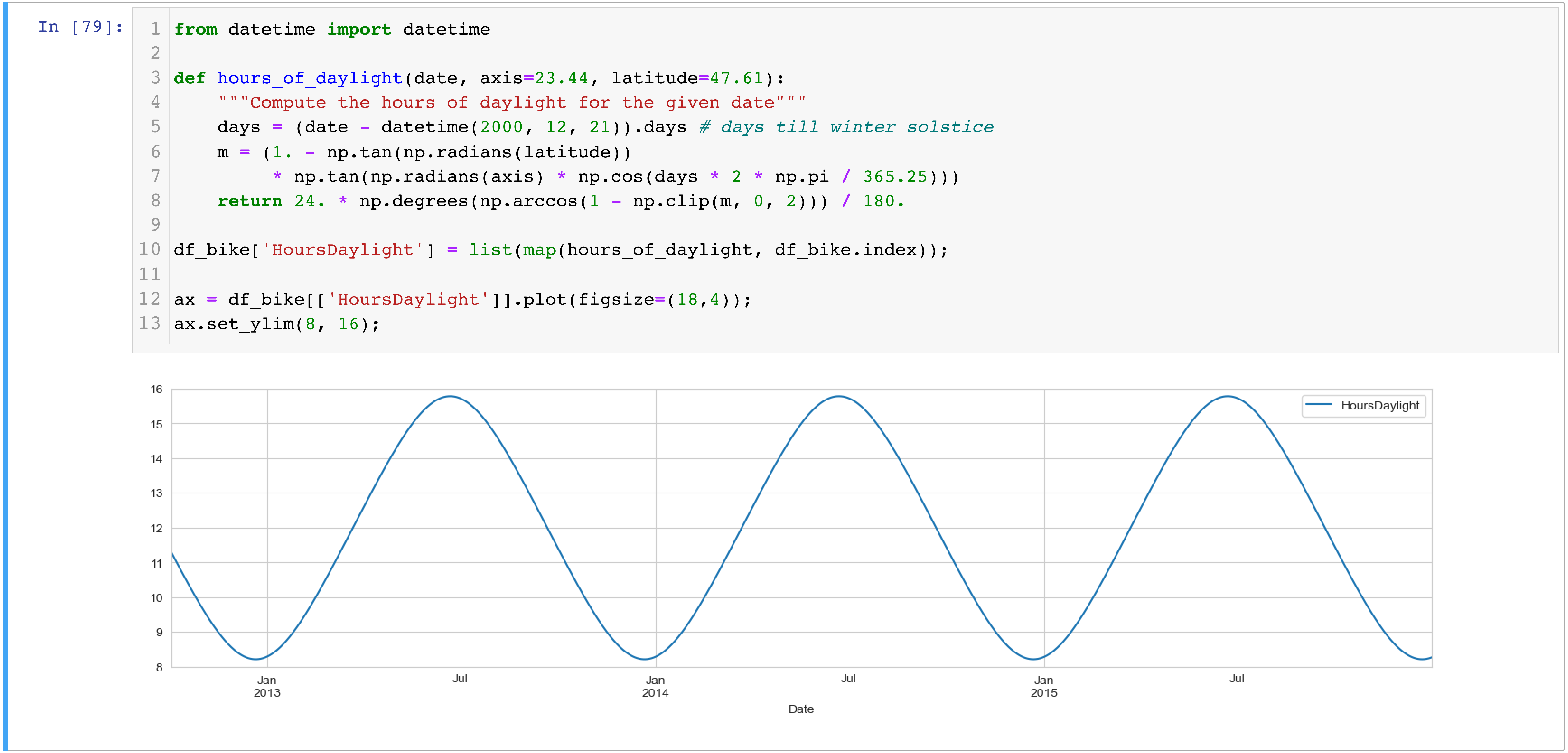


```python
from pandas.tseries.holiday import USFederalHolidayCalendar
cal = USFederalHolidayCalendar()
holidays = cal.holidays('2012', '2016')

df_bike = df_bike.join(pd.Series(1, index=holidays, name='IsHoliday'))
df_bike['IsHoliday'].fillna(0, inplace=True)
print(df_bike.head(3))
```

```
             Total DayOfWeek  IsHoliday
Date                                   
2012-10-03  3521.0       Wed        0.0
2012-10-04  3475.0       Thu        0.0
2012-10-05  3148.0       Fri        0.0
```

Add number of hours of daylight

Add number of hours of daylight

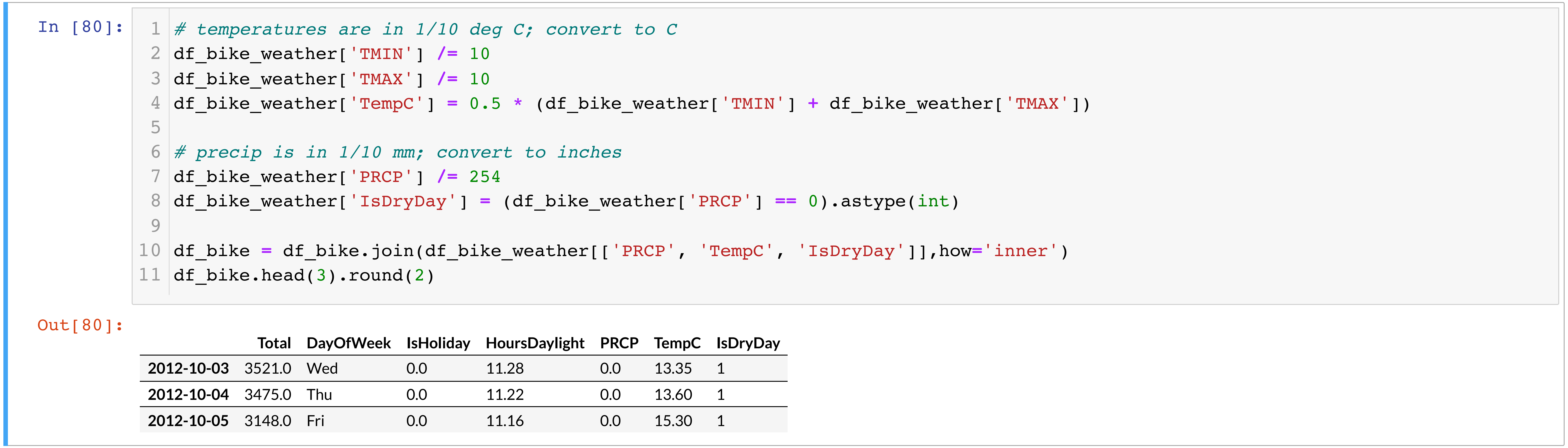


In [79]:

```
from datetime import datetime

def hours_of_daylight(date, axis=23.44, latitude=47.61):
    """Compute the hours of daylight for the given date"""
    days = (date - datetime(2000, 12, 21)).days # days till winter solstice
    m = (1. - np.tan(np.radians(latitude))
         * np.tan(np.radians(axis) * np.cos(days * 2 * np.pi / 365.25)))
    return 24. * np.degrees(np.arccos(1 - np.clip(m, 0, 2))) / 180.

df_bike['HoursDaylight'] = list(map(hours_of_daylight, df_bike.index));

ax = df_bike[['HoursDaylight']].plot(figsize=(18,4));
ax.set_ylim(8, 16);
```

Add weather information (Q: can we predict this for future dates?)

Add weather information (Q: can we predict this for future dates?)



In [80]:

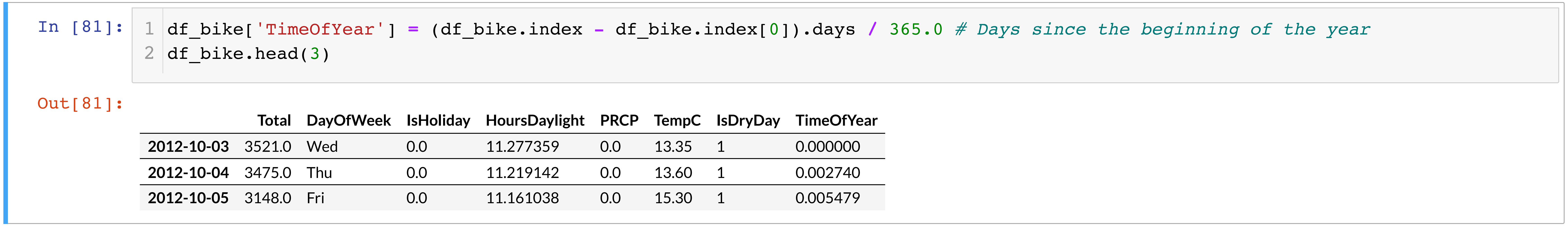
```python
# temperatures are in 1/10 deg C; convert to C
df_bike_weather['TMIN'] /= 10
df_bike_weather['TMAX'] /= 10
df_bike_weather['TempC'] = 0.5 * (df_bike_weather['TMIN'] + df_bike_weather['TMAX'])

# precip is in 1/10 mm; convert to inches
df_bike_weather['PRCP'] /= 254
df_bike_weather['IsDryDay'] = (df_bike_weather['PRCP'] == 0).astype(int)

df_bike = df_bike.join(df_bike_weather[['PRCP', 'TempC', 'IsDryDay']],how='inner')
df_bike.head(3).round(2)
```

Out[80]:

	Total	DayOfWeek	IsHoliday	HoursDaylight	PRCP	TempC	IsDryDay
2012-10-03	3521.0	Wed	0.0	11.28	0.0	13.35	1
2012-10-04	3475.0	Thu	0.0	11.22	0.0	13.60	1
2012-10-05	3148.0	Fri	0.0	11.16	0.0	15.30	1

Add time of year

Add time of year



In [81]:

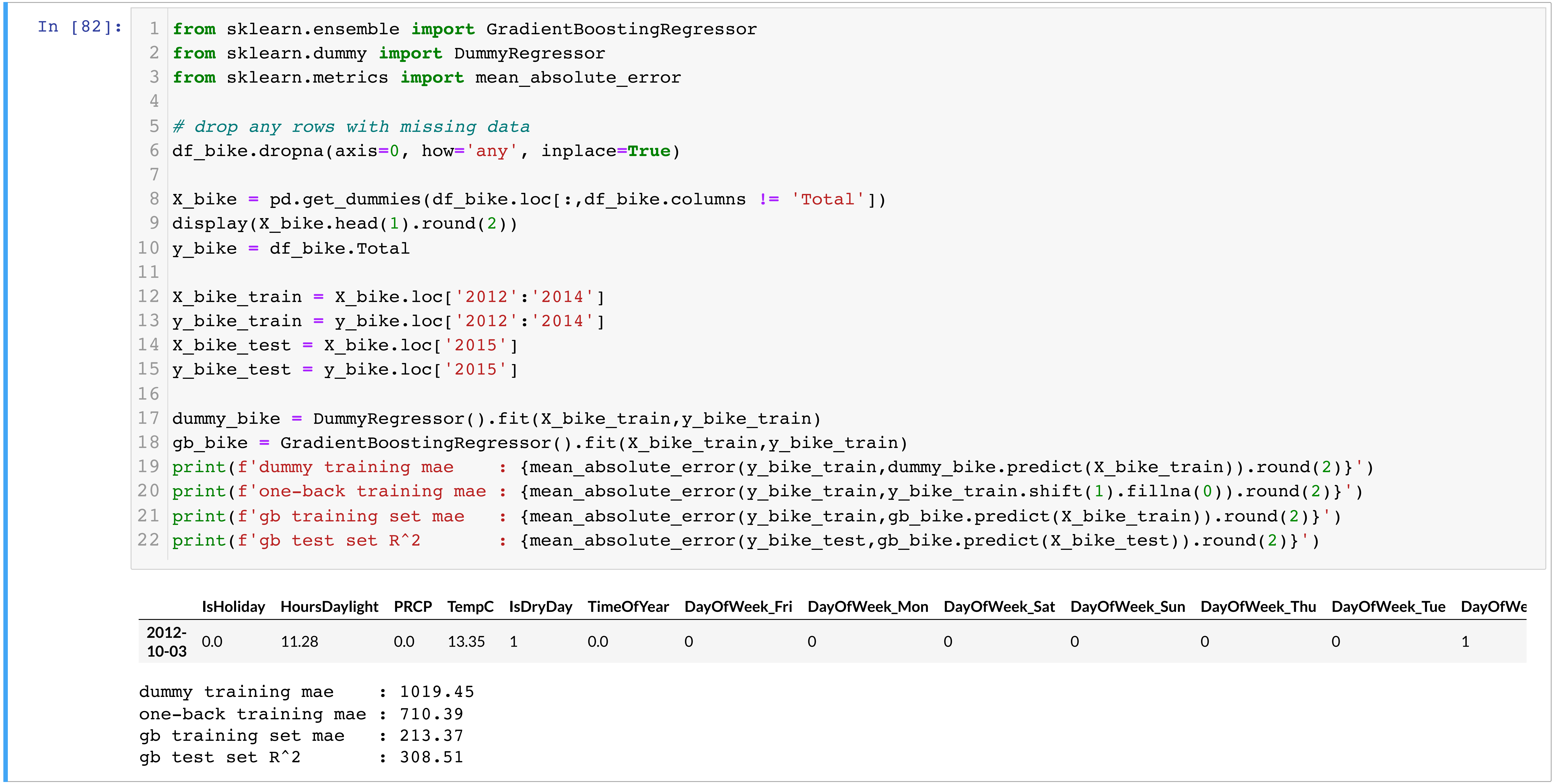
```
df_bike['TimeOfYear'] = (df_bike.index - df_bike.index[0]).days / 365.0 # Days since the beginning of the year
df_bike.head(3)
```

Out[81]:

	Total	DayOfWeek	IsHoliday	HoursDaylight	PRCP	TempC	IsDryDay	TimeOfYear
2012-10-03	3521.0	Wed	0.0	11.277359	0.0	13.35	1	0.000000
2012-10-04	3475.0	Thu	0.0	11.219142	0.0	13.60	1	0.002740
2012-10-05	3148.0	Fri	0.0	11.161038	0.0	15.30	1	0.005479

Generate and evaluate a model

Generate and evaluate a model



In [82]:

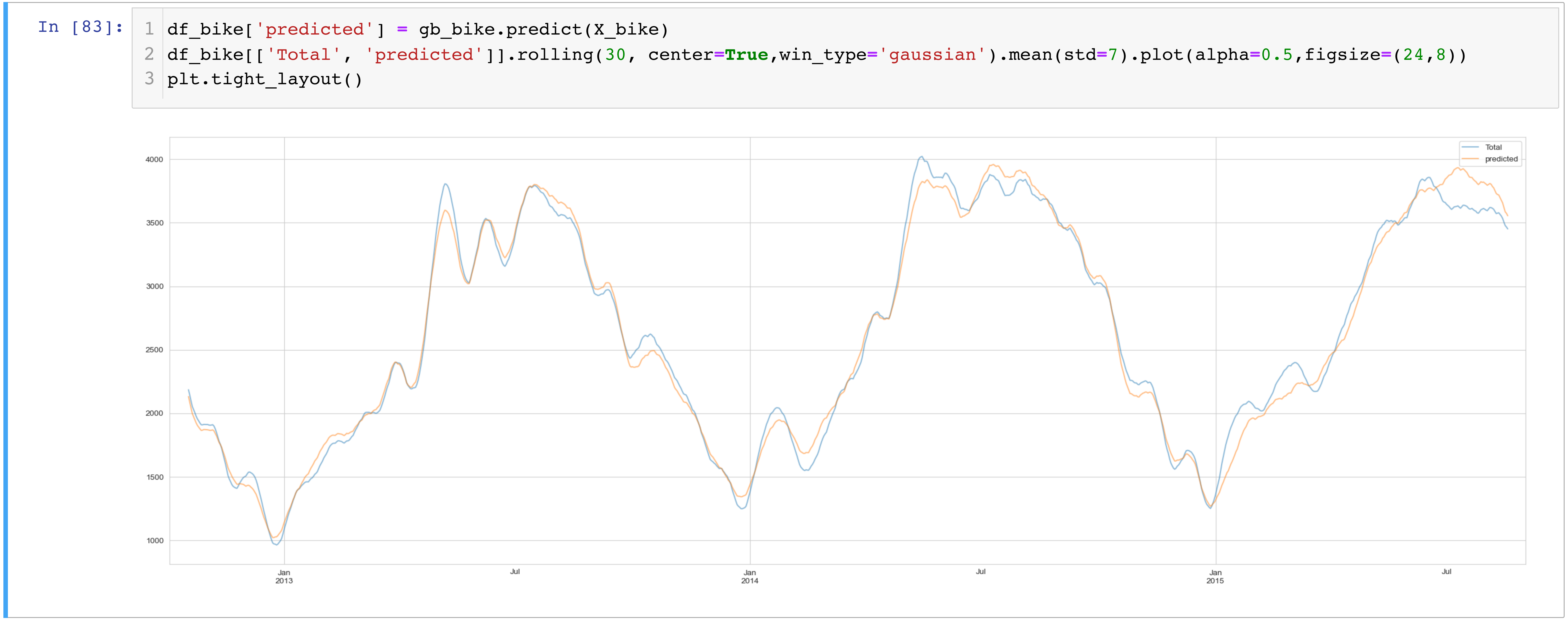
```python
from sklearn.ensemble import GradientBoostingRegressor
from sklearn.dummy import DummyRegressor
from sklearn.metrics import mean_absolute_error

# drop any rows with missing data
df_bike.dropna(axis=0, how='any', inplace=True)

X_bike = pd.get_dummies(df_bike.loc[:,df_bike.columns != 'Total'])
display(X_bike.head(1).round(2))
y_bike = df_bike.Total

X_bike_train = X_bike.loc['2012':'2014']
y_bike_train = y_bike.loc['2012':'2014']
X_bike_test = X_bike.loc['2015']
y_bike_test = y_bike.loc['2015']

dummy_bike = DummyRegressor().fit(X_bike_train,y_bike_train)
gb_bike = GradientBoostingRegressor().fit(X_bike_train,y_bike_train)
print(f'dummy training mae     : {mean_absolute_error(y_bike_train,dummy_bike.predict(X_bike_train)).round(2)}')
print(f'one-back training mae : {mean_absolute_error(y_bike_train,y_bike_train.shift(1).fillna(0)).round(2)}')
print(f'gb training set mae    : {mean_absolute_error(y_bike_train,gb_bike.predict(X_bike_train)).round(2)}')
print(f'gb test set R^2        : {mean_absolute_error(y_bike_test,gb_bike.predict(X_bike_test)).round(2)}')
```

	IsHoliday	HoursDaylight	PRCP	TempC	IsDryDay	TimeOfYear	DayOfWeek_Fri	DayOfWeek_Mon	DayOfWeek_Sat	DayOfWeek_Sun	DayOfWeek_Thu	DayOfWeek_Tue	DayOfWe
2012-10-03	0.0	11.28	0.0	13.35	1	0.0	0	0	0	0	0	0	1

```
dummy training mae     : 1019.45
one-back training mae : 710.39
gb training set mae    : 213.37
gb test set R^2        : 308.51
```

Plot predictions vs observed

Plot predictions vs observed



In [83]:

```
df_bike['predicted'] = gb_bike.predict(X_bike)
df_bike[['Total', 'predicted']].rolling(30, center=True,win_type='gaussian').mean(std=7).plot(alpha=0.5,figsize=(24,8))
plt.tight_layout()
```

Time Series Operations Review

- Shifting
- Resampling
    - Downsampling
    - Upsampling
- Moving/Rolling Windows

- for more info, including time-series cross-validation:
    - sklearn: Time-related feature engineering
    - PML Chapter 13 - Modeling Sequential Data Using Recurrent Neural Network (with Tensorflow)

- for more models:
    - skforecast
    - statsmodels

Questions re Time Series Transformations?