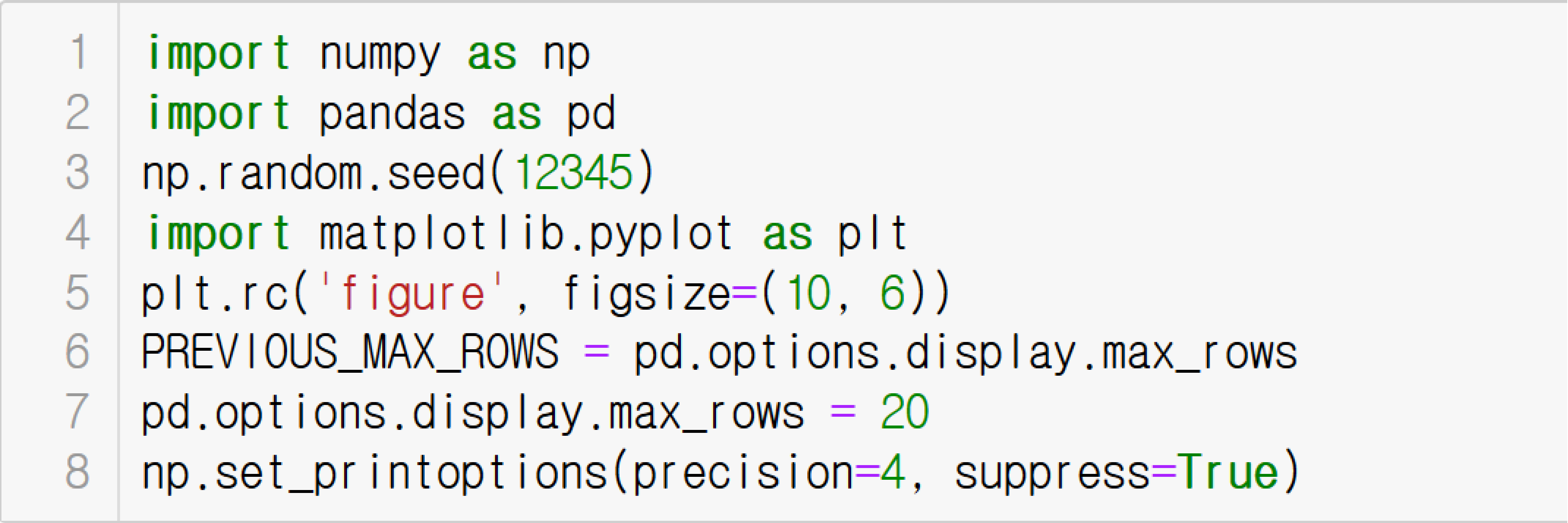
Python
for Data Analysis

Time Series

Time Series Data

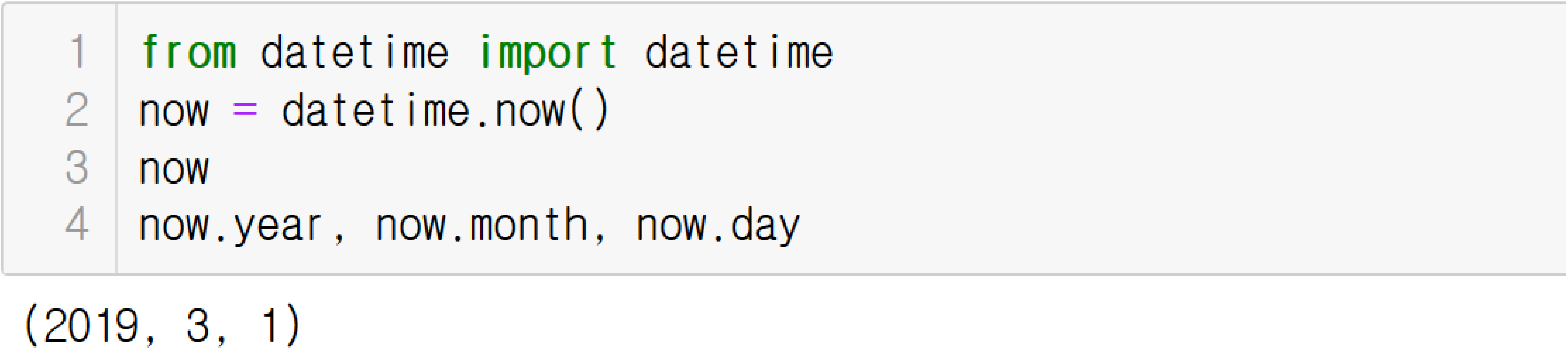
- *Timestamps*, specific instants in time
- Fixed *periods*, such as the month January 2007 or the full year 2010
- *Intervals* of time, indicated by a start and end timestamp. Periods can be thought of as special cases of intervals
- Experiment or elapsed time; each timestamp is a measure of time relative to a particular start time. For example, the diameter of a cookie baking each second since being placed in the oven

Basic Settings



```python
import numpy as np
import pandas as pd
np.random.seed(12345)
import matplotlib.pyplot as plt
plt.rc('figure', figsize=(10, 6))
PREVIOUS_MAX_ROWS = pd.options.display.max_rows
pd.options.display.max_rows = 20
np.set_printoptions(precision=4, suppress=True)
```

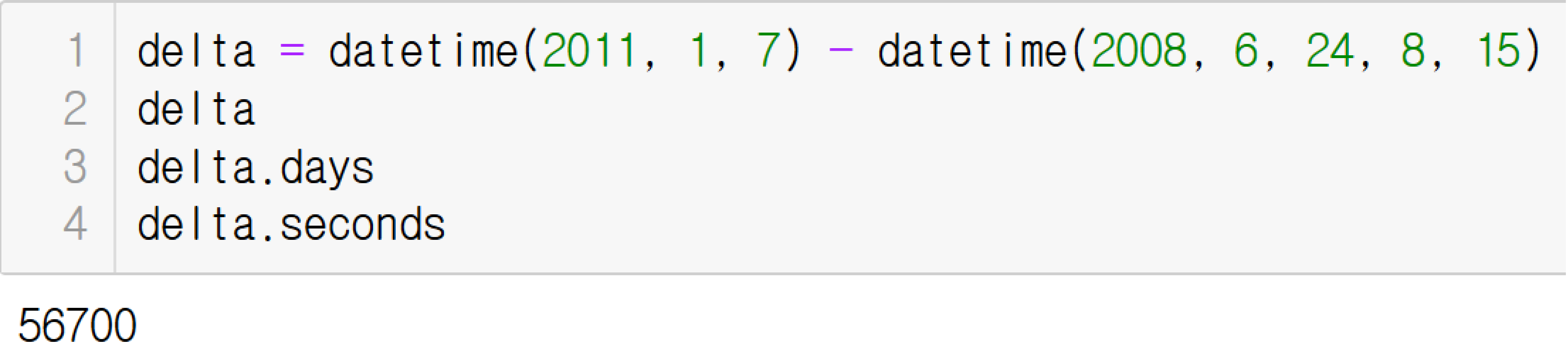
Date and Time Data Types and Tools



```python
from datetime import datetime
now = datetime.now()
now
now.year, now.month, now.day
```

```
(2019, 3, 1)
```

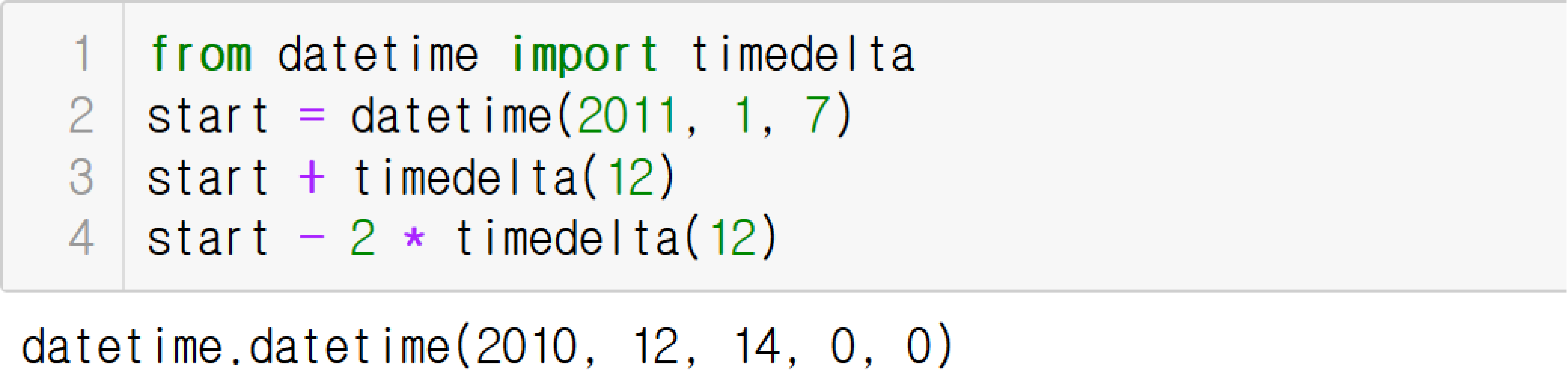
Date and Time Data Types and Tools



```python
delta = datetime(2011, 1, 7) - datetime(2008, 6, 24, 8, 15)
delta
delta.days
delta.seconds
```

```
56700
```

Date and Time Data Types and Tools

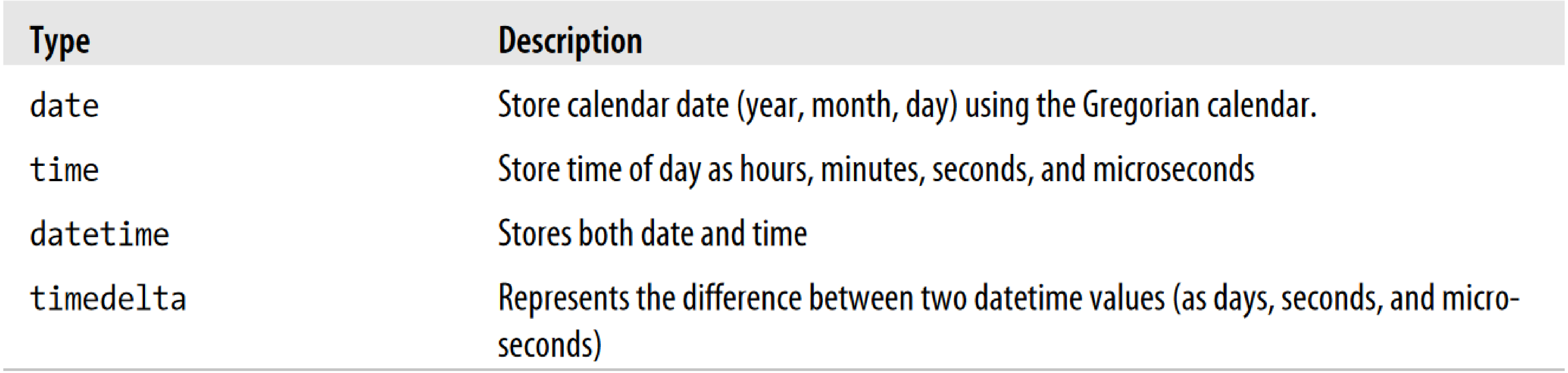


```python
from datetime import timedelta
start = datetime(2011, 1, 7)
start + timedelta(12)
start - 2 * timedelta(12)
```

```
datetime.datetime(2010, 12, 14, 0, 0)
```

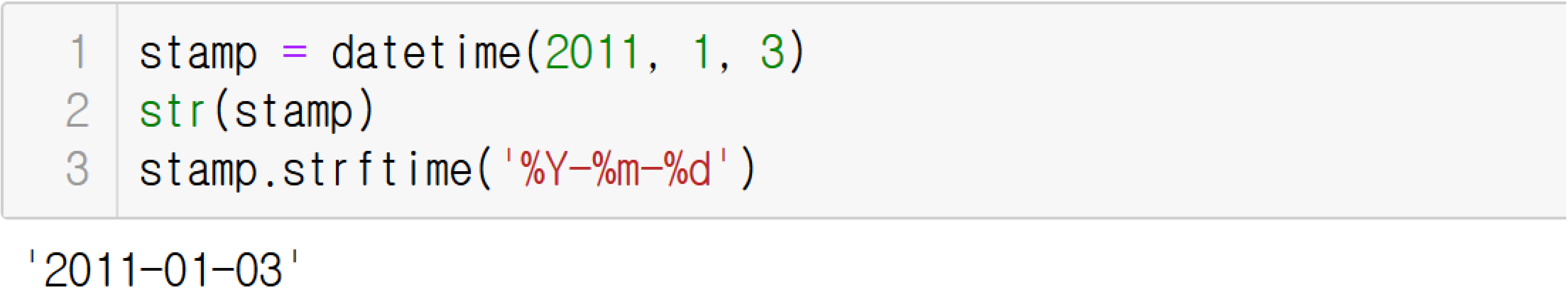
Date and Time Data Types and Tools

Types in datetime module



Type	Description
`date`	Store calendar date (year, month, day) using the Gregorian calendar.
`time`	Store time of day as hours, minutes, seconds, and microseconds
`datetime`	Stores both date and time
`timedelta`	Represents the difference between two datetime values (as days, seconds, and microseconds)

Converting Between String and Datetime

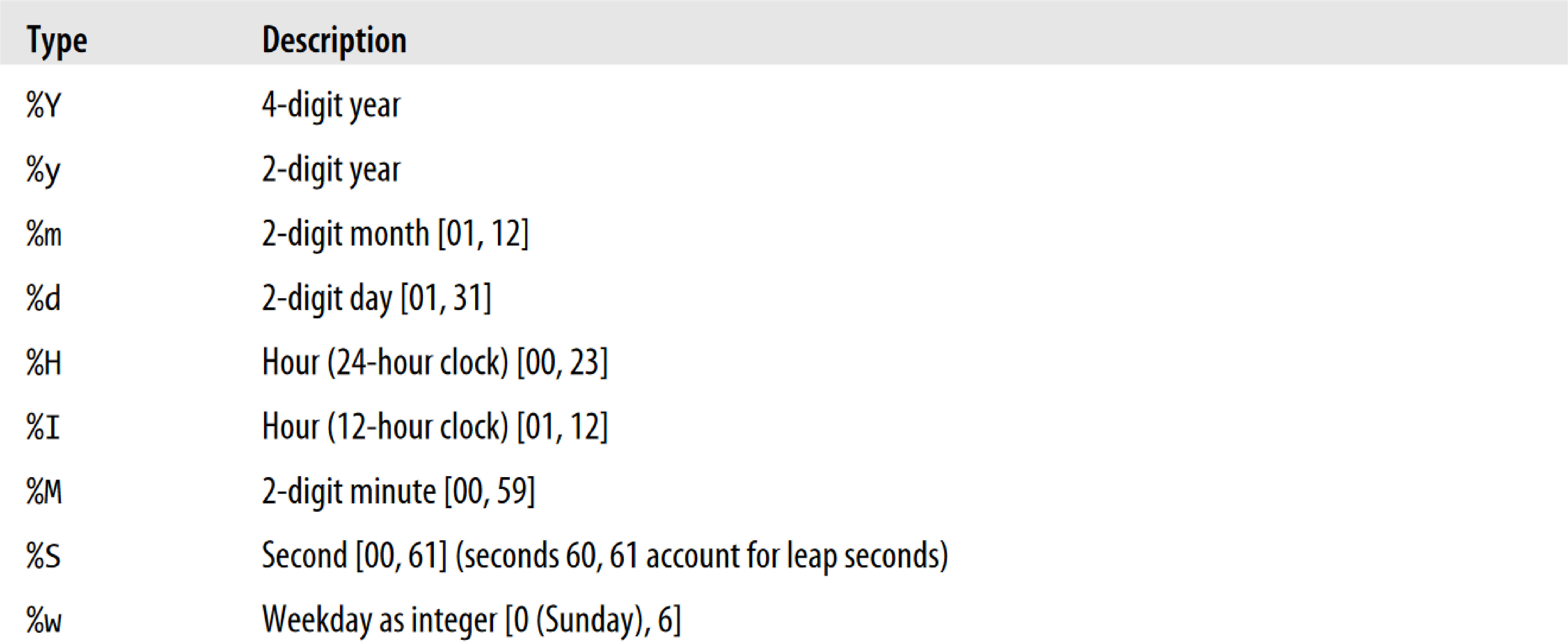


```
stamp = datetime(2011, 1, 3)
str(stamp)
stamp.strftime('%Y-%m-%d')
```

```
'2011-01-03'
```

Converting Between String and Datetime

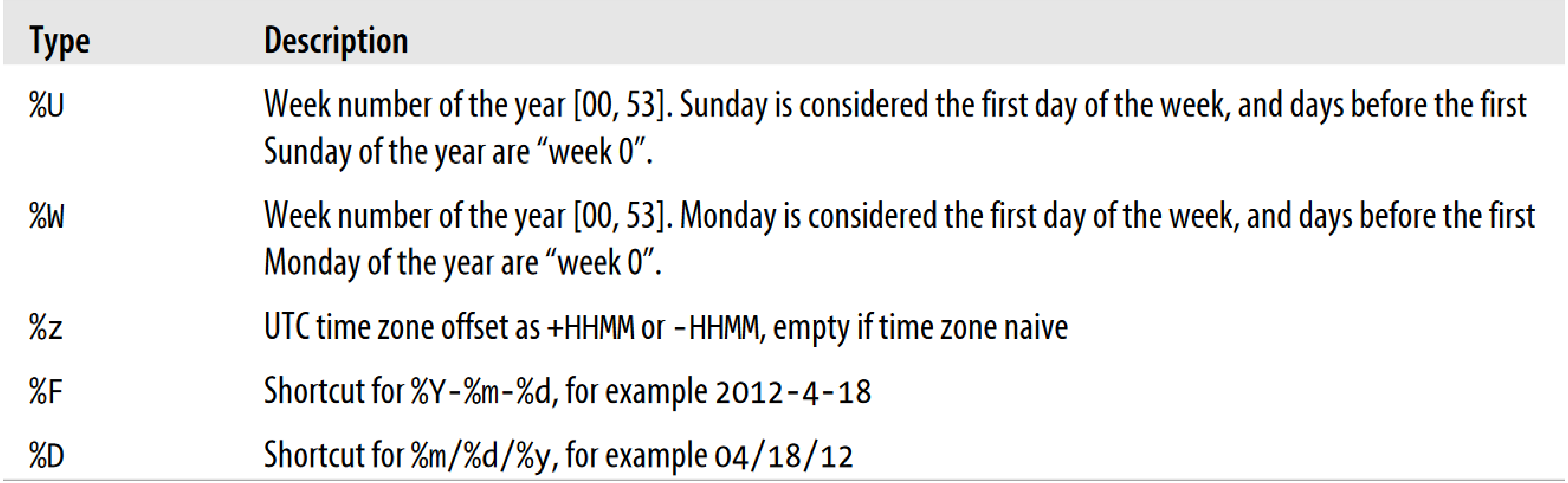
Datetime format specification (ISO C89 compatible)



Type	Description
%Y	4-digit year
%y	2-digit year
%m	2-digit month [01, 12]
%d	2-digit day [01, 31]
%H	Hour (24-hour clock) [00, 23]
%I	Hour (12-hour clock) [01, 12]
%M	2-digit minute [00, 59]
%S	Second [00, 61] (seconds 60, 61 account for leap seconds)
%w	Weekday as integer [0 (Sunday), 6]

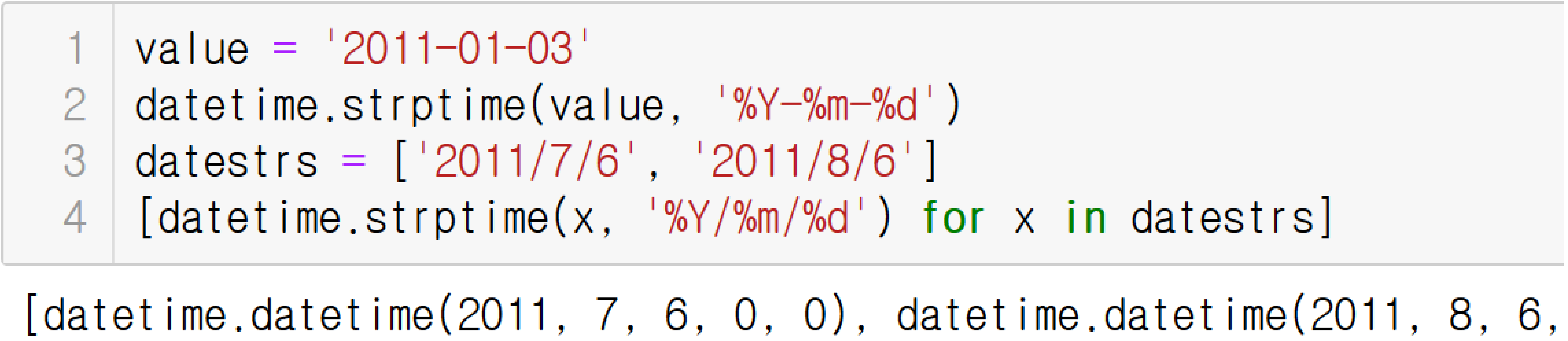
Converting Between String and Datetime

Datetime format specification (ISO C89 compatible)



Type	Description
%U	Week number of the year [00, 53]. Sunday is considered the first day of the week, and days before the first Sunday of the year are “week 0”.
%W	Week number of the year [00, 53]. Monday is considered the first day of the week, and days before the first Monday of the year are “week 0”.
%z	UTC time zone offset as +HHMM or -HHMM, empty if time zone naive
%F	Shortcut for %Y-%m-%d, for example 2012-4-18
%D	Shortcut for %m/%d/%y, for example 04/18/12

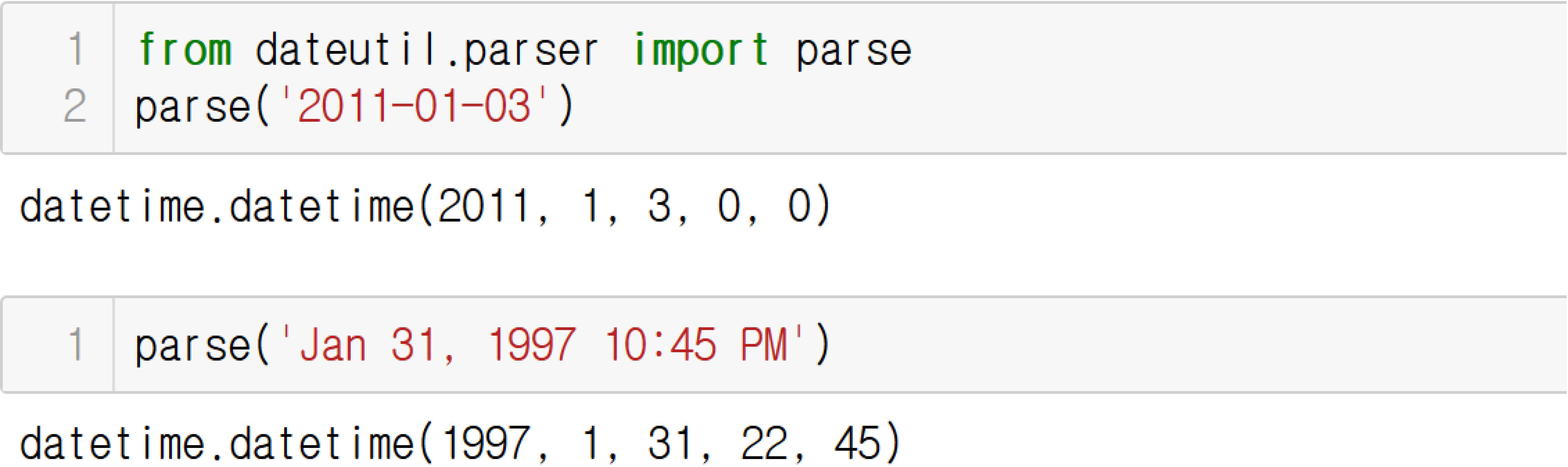
Converting Between String and Datetime



```python
value = '2011-01-03'
datetime.strptime(value, '%Y-%m-%d')
datestrs = ['2011/7/6', '2011/8/6']
[datetime.strptime(x, '%Y/%m/%d') for x in datestrs]
```

```
[datetime.datetime(2011, 7, 6, 0, 0), datetime.datetime(2011, 8, 6,
```

Converting Between String and Datetime



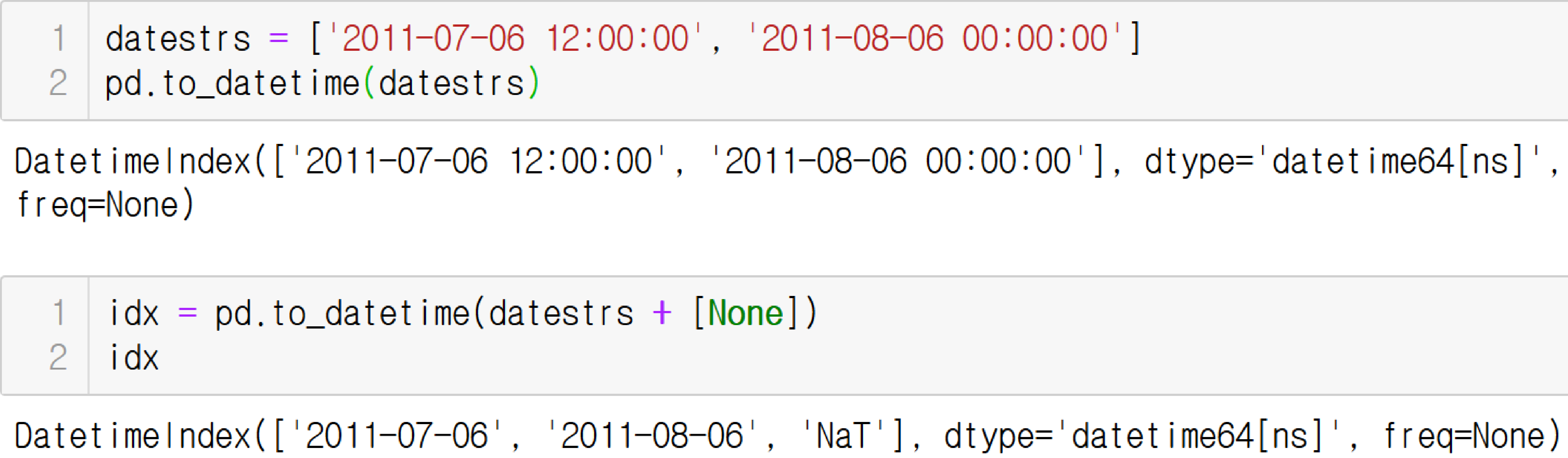
```python
from dateutil.parser import parse
parse('2011-01-03')
```

```
datetime.datetime(2011, 1, 3, 0, 0)
```

```python
parse('Jan 31, 1997 10:45 PM')
```

```
datetime.datetime(1997, 1, 31, 22, 45)
```

Converting Between String and Datetime



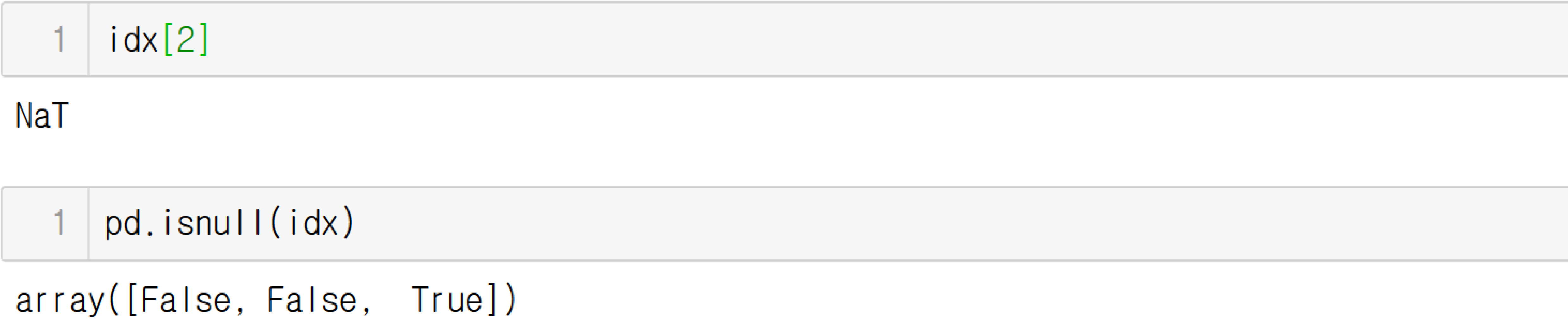
```
datestrs = ['2011-07-06 12:00:00', '2011-08-06 00:00:00']
pd.to_datetime(datestrs)
```

```
DatetimeIndex(['2011-07-06 12:00:00', '2011-08-06 00:00:00'], dtype='datetime64[ns]',
freq=None)
```

```
idx = pd.to_datetime(datestrs + [None])
idx
```

```
DatetimeIndex(['2011-07-06', '2011-08-06', 'NaT'], dtype='datetime64[ns]', freq=None)
```

Converting Between String and Datetime



```
idx[2]
```

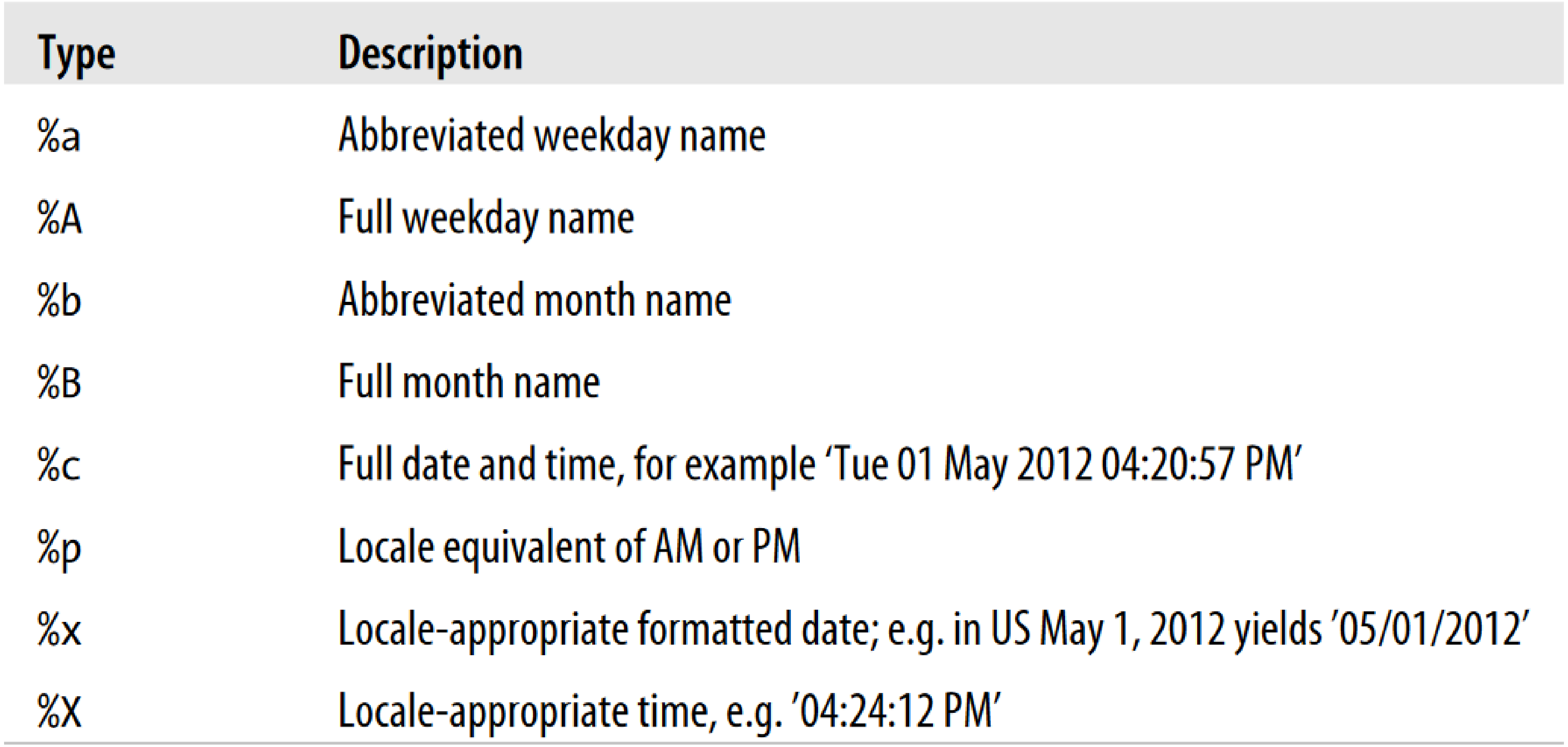
```
NaT
```

```
pd.isnull(idx)
```

```
array([False, False,  True])
```

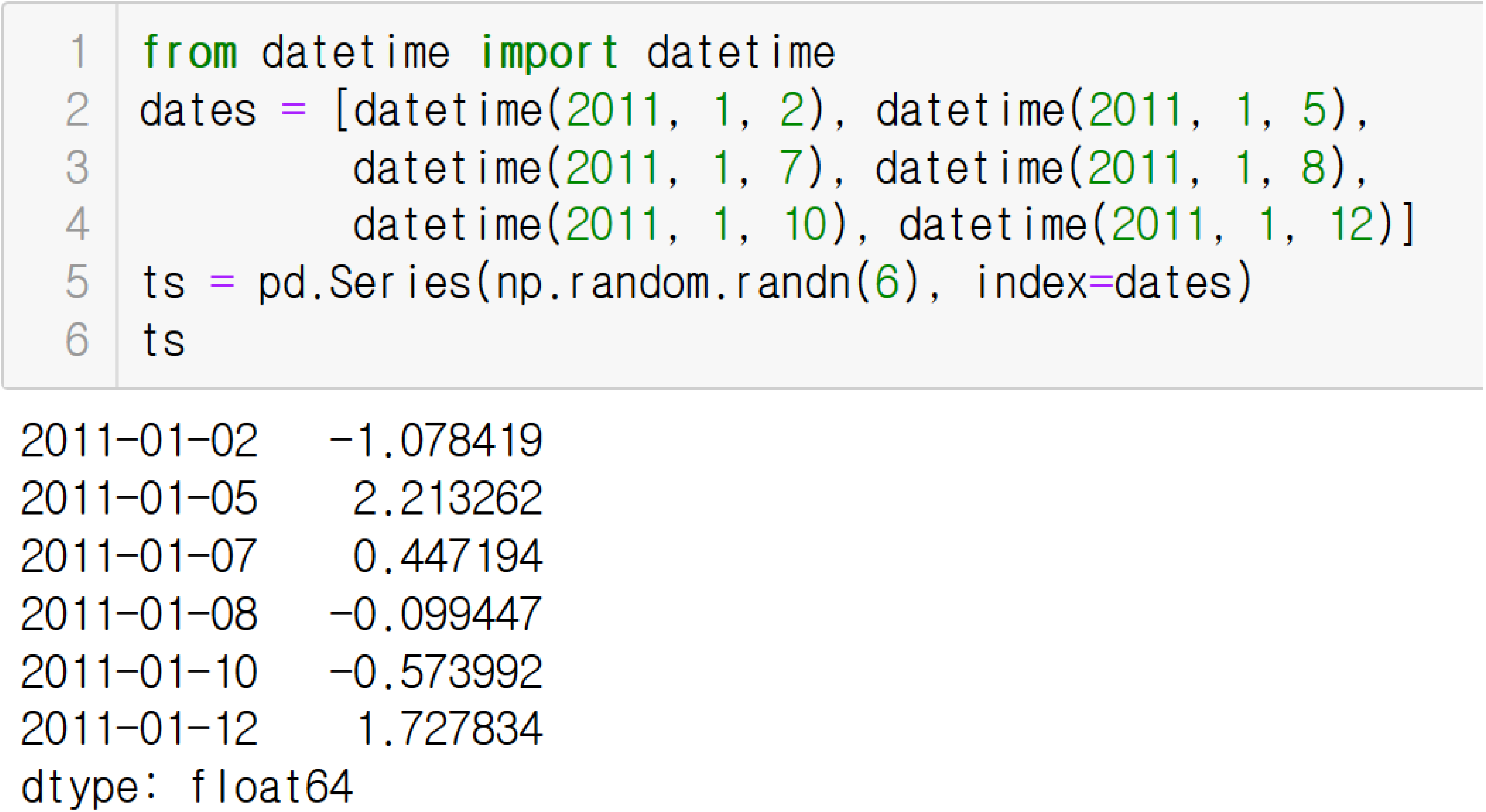
Converting Between String and Datetime

Locale-specific date formatting



Type	Description
%a	Abbreviated weekday name
%A	Full weekday name
%b	Abbreviated month name
%B	Full month name
%c	Full date and time, for example ‘Tue 01 May 2012 04:20:57 PM’
%p	Locale equivalent of AM or PM
%x	Locale-appropriate formatted date; e.g. in US May 1, 2012 yields ’05/01/2012’
%X	Locale-appropriate time, e.g. ’04:24:12 PM’

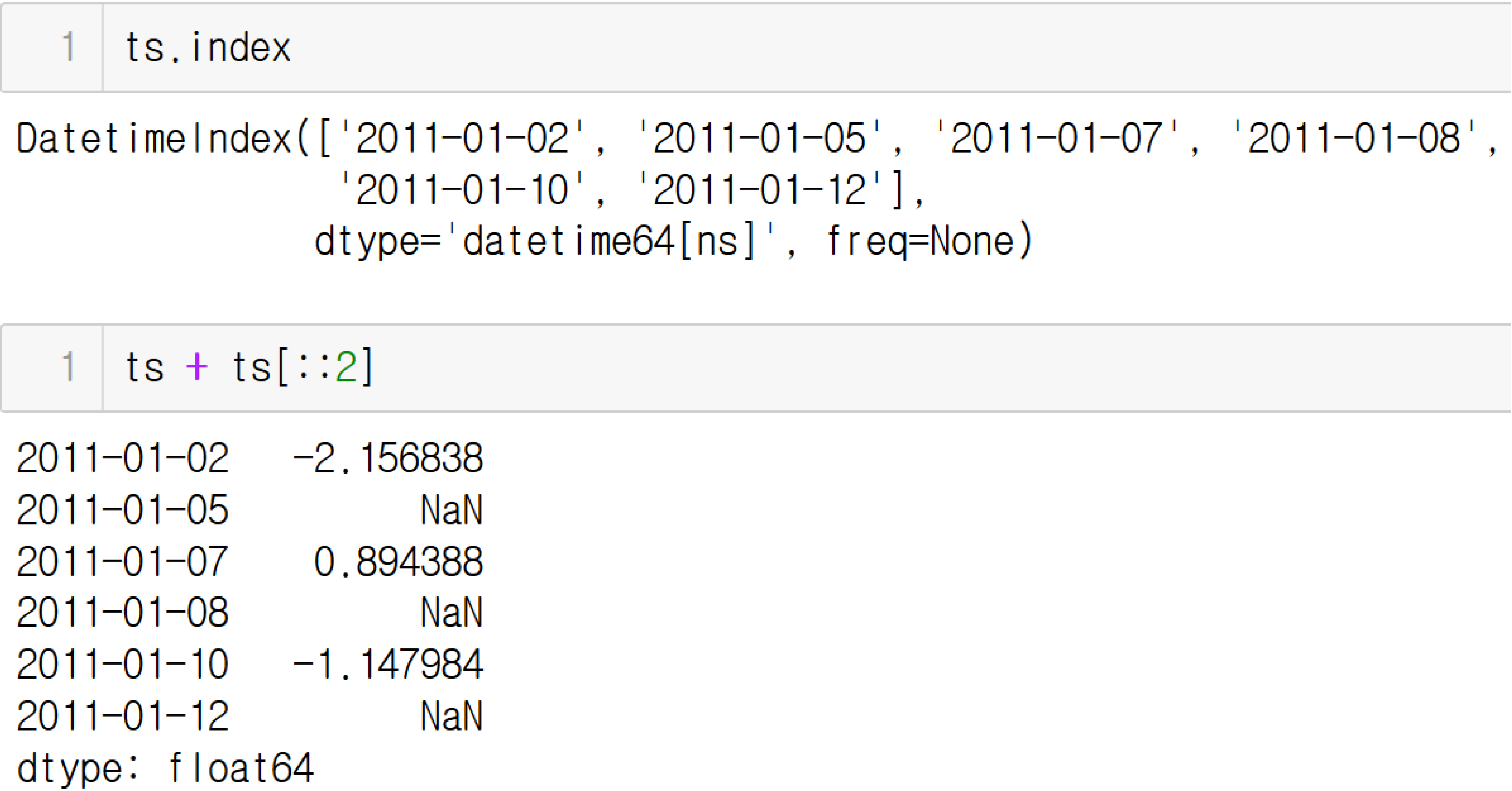
Time Series Basics



```python
from datetime import datetime
dates = [datetime(2011, 1, 2), datetime(2011, 1, 5),
         datetime(2011, 1, 7), datetime(2011, 1, 8),
         datetime(2011, 1, 10), datetime(2011, 1, 12)]
ts = pd.Series(np.random.randn(6), index=dates)
ts
```

```
2011-01-02   -1.078419
2011-01-05    2.213262
2011-01-07    0.447194
2011-01-08   -0.099447
2011-01-10   -0.573992
2011-01-12    1.727834
dtype: float64
```

Time Series Basics



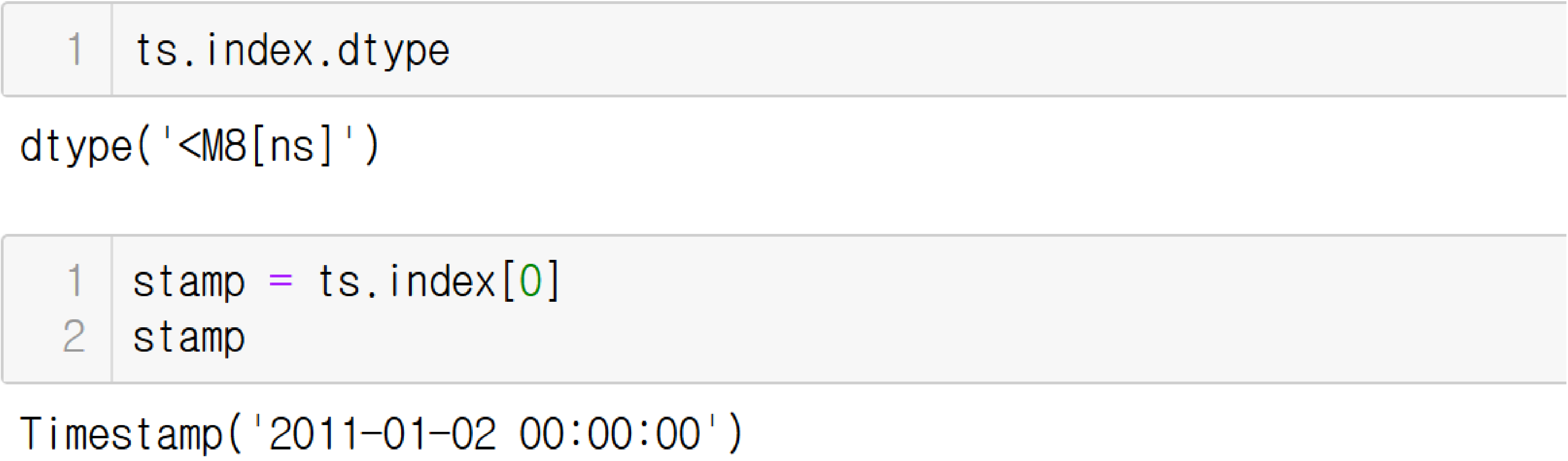
```
ts.index
```

```
DatetimeIndex(['2011-01-02', '2011-01-05', '2011-01-07', '2011-01-08',
               '2011-01-10', '2011-01-12'],
              dtype='datetime64[ns]', freq=None)
```

```
ts + ts[::2]
```

```
2011-01-02   -2.156838
2011-01-05         NaN
2011-01-07    0.894388
2011-01-08         NaN
2011-01-10   -1.147984
2011-01-12         NaN
dtype: float64
```

Time Series Basics



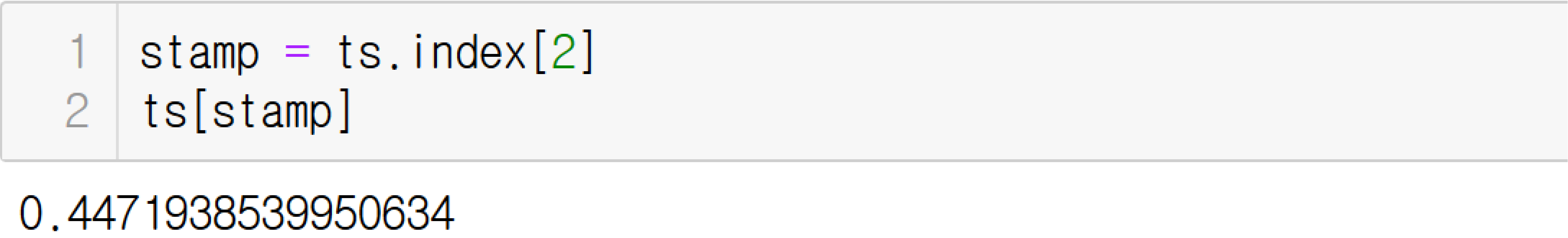
```
ts.index.dtype
```

```
dtype('<M8[ns]')
```

```
stamp = ts.index[0]
stamp
```

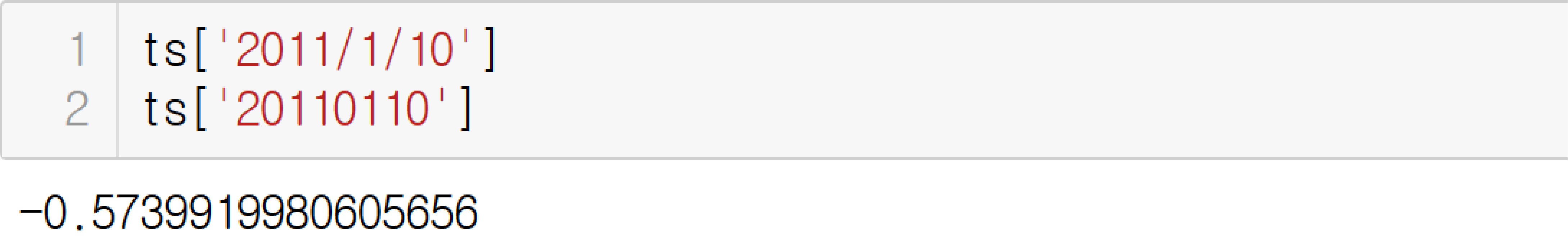
```
Timestamp('2011-01-02 00:00:00')
```

Indexing, Selection, Subsetting



```
stamp = ts.index[2]
ts[stamp]
```

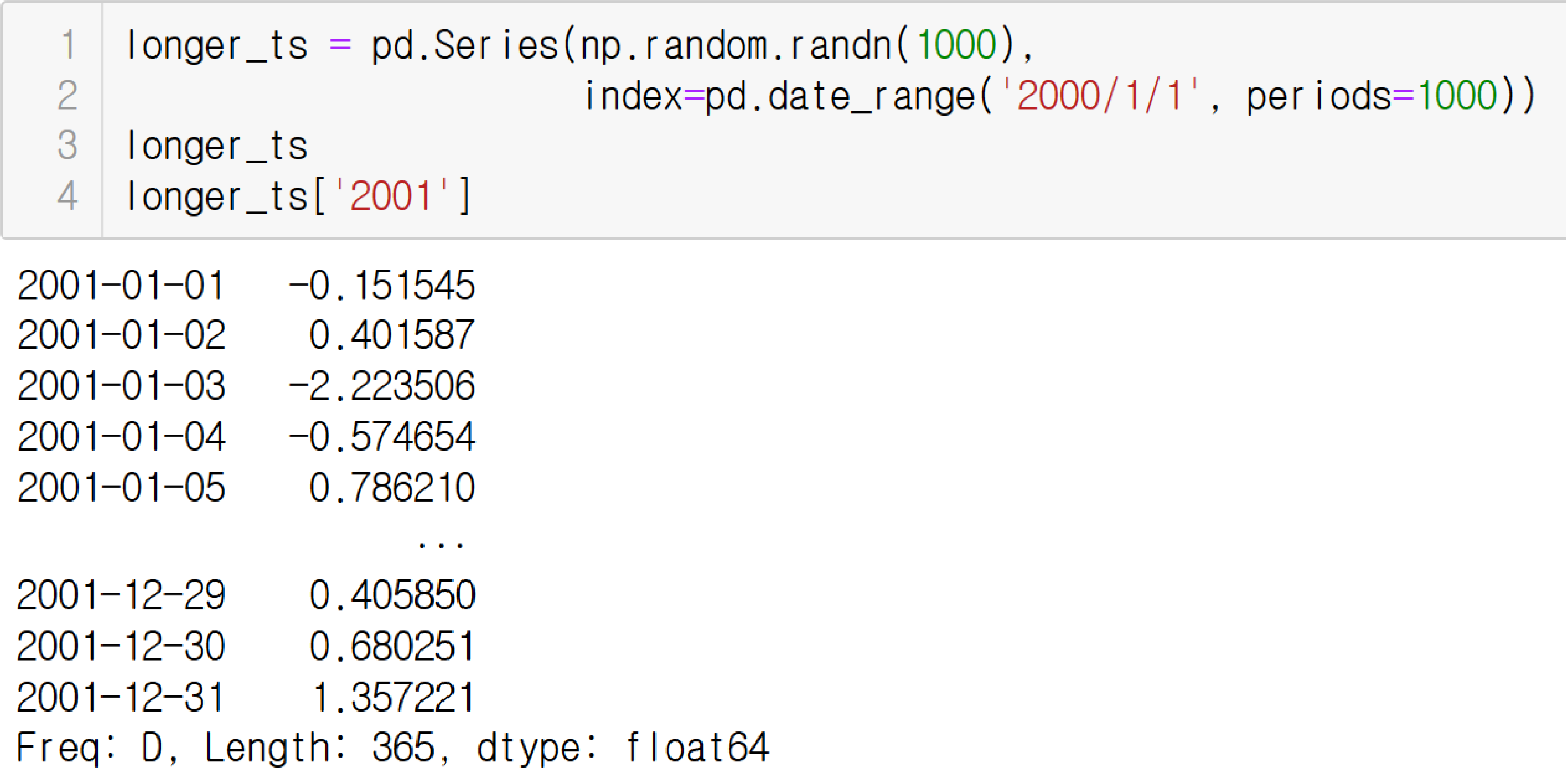
```
0.4471938539950634
```



```
ts['2011/1/10']
ts['20110110']
```

```
-0.5739919980605656
```

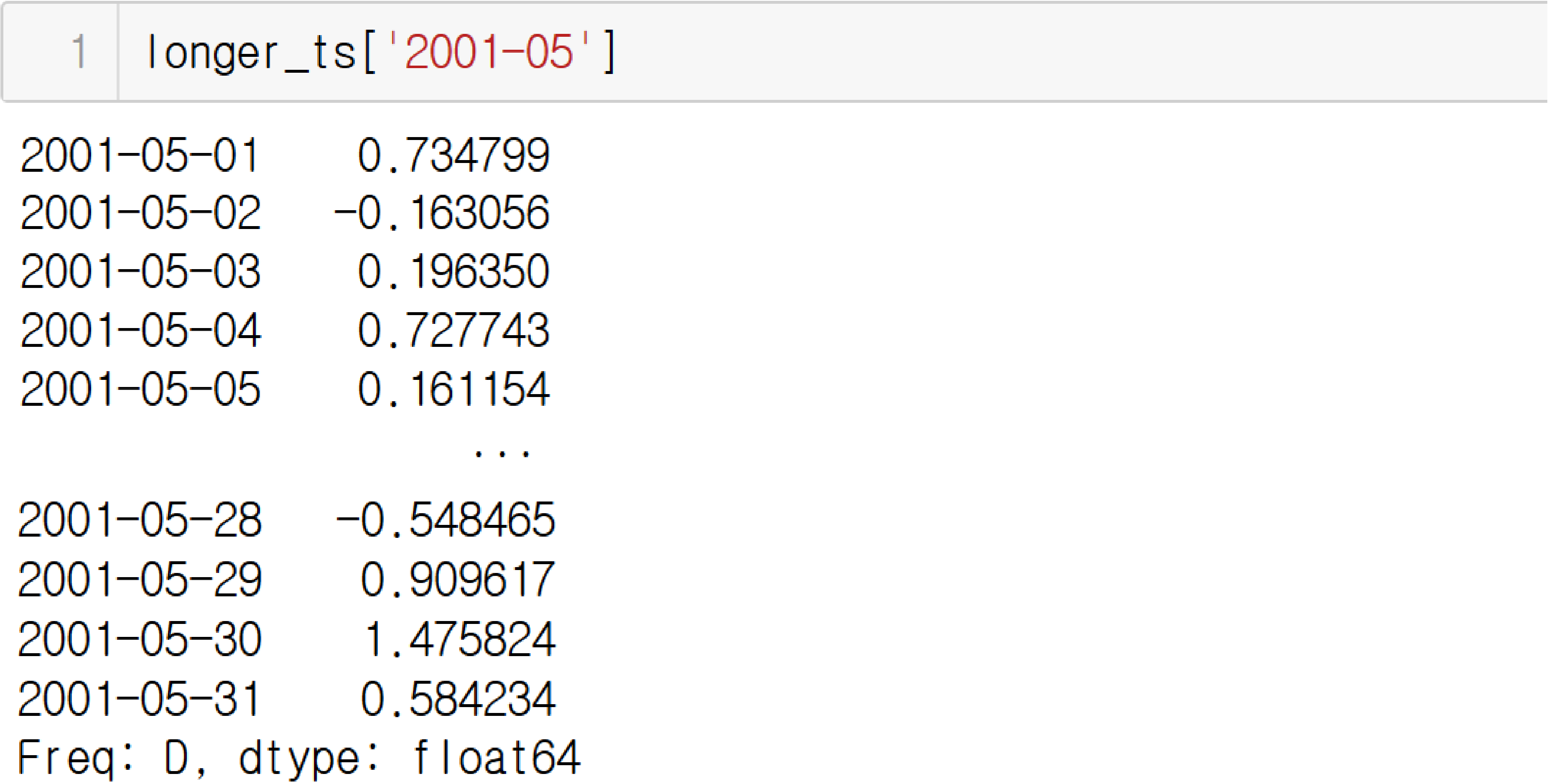
Indexing, Selection, Subsetting



```
longer_ts = pd.Series(np.random.randn(1000),
                      index=pd.date_range('2000/1/1', periods=1000))
longer_ts
longer_ts['2001']
```

```
2001-01-01   -0.151545
2001-01-02    0.401587
2001-01-03   -2.223506
2001-01-04   -0.574654
2001-01-05    0.786210
                 ...
2001-12-29    0.405850
2001-12-30    0.680251
2001-12-31    1.357221
Freq: D, Length: 365, dtype: float64
```

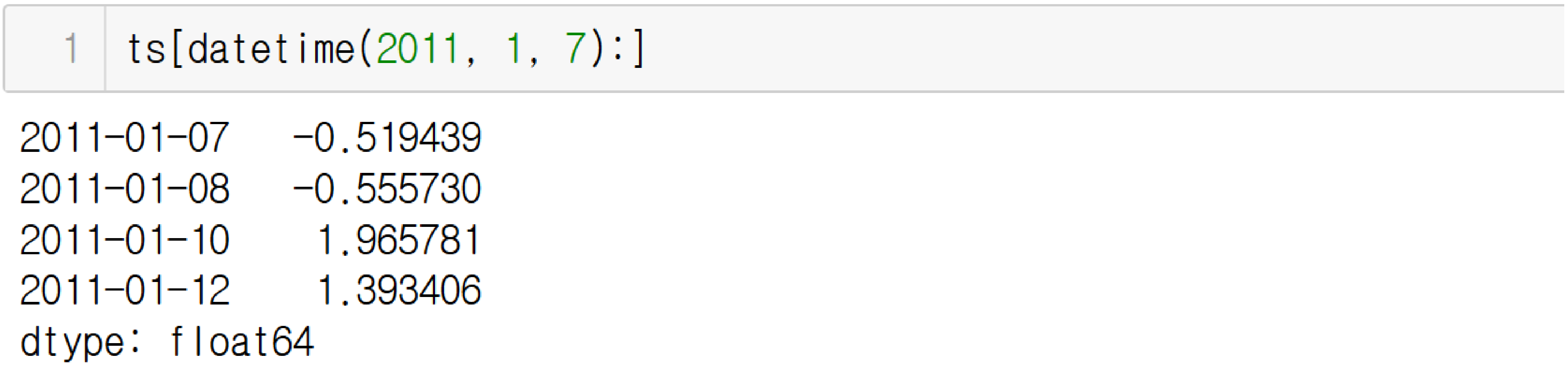
Indexing, Selection, Subsetting



```python
longer_ts['2001-05']
```

```
2001-05-01    0.734799
2001-05-02   -0.163056
2001-05-03    0.196350
2001-05-04    0.727743
2001-05-05    0.161154
                 ...
2001-05-28   -0.548465
2001-05-29    0.909617
2001-05-30    1.475824
2001-05-31    0.584234
Freq: D, dtype: float64
```

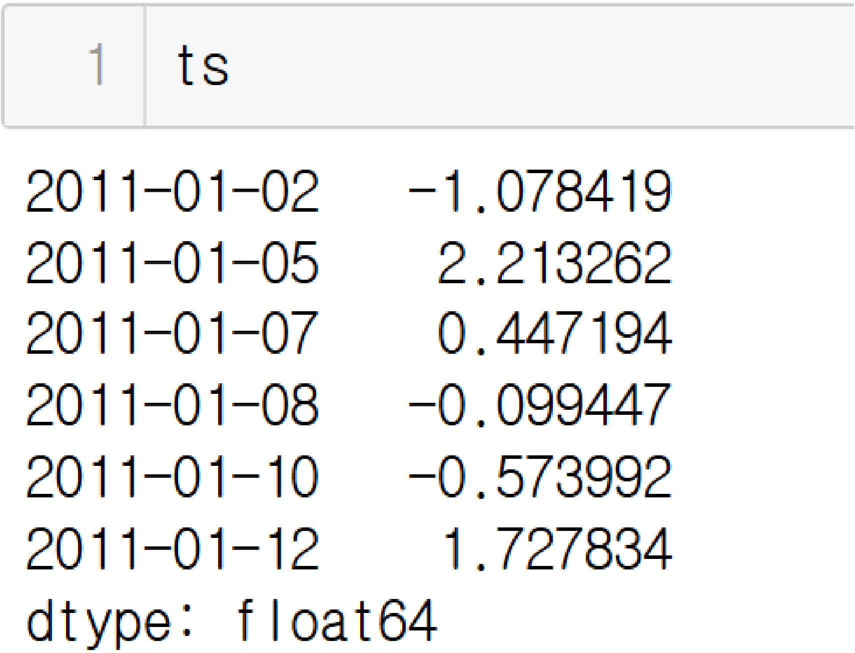
Indexing, Selection, Subsetting



```
ts[datetime(2011, 1, 7):]
```

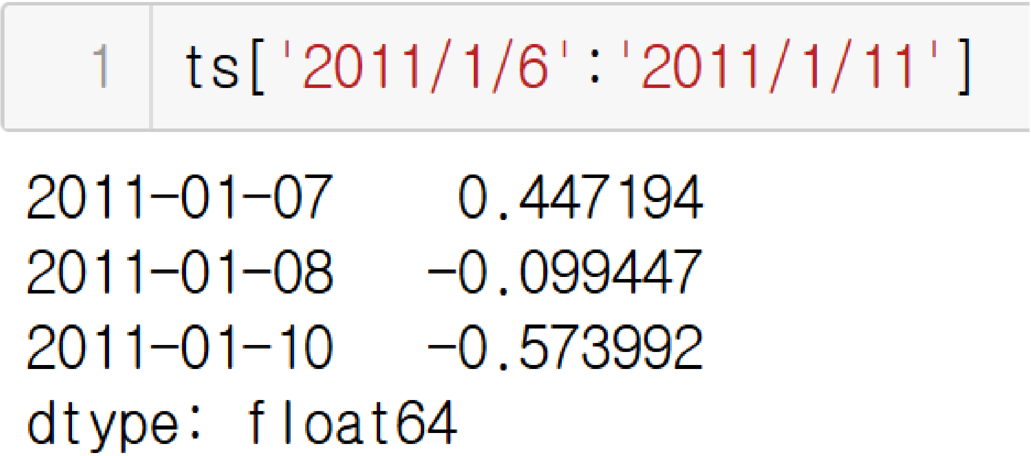
```
2011-01-07   -0.519439
2011-01-08   -0.555730
2011-01-10    1.965781
2011-01-12    1.393406
dtype: float64
```

Indexing, Selection, Subsetting



```
ts
```

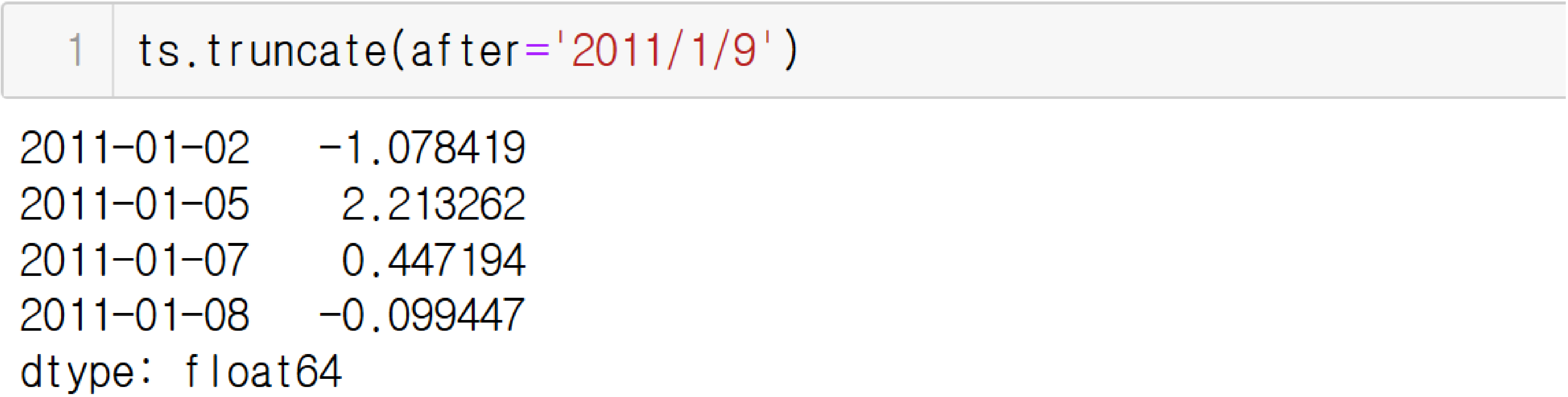
```
2011-01-02   -1.078419
2011-01-05    2.213262
2011-01-07    0.447194
2011-01-08   -0.099447
2011-01-10   -0.573992
2011-01-12    1.727834
dtype: float64
```



```
ts['2011/1/6':'2011/1/11']
```

```
2011-01-07    0.447194
2011-01-08   -0.099447
2011-01-10   -0.573992
dtype: float64
```

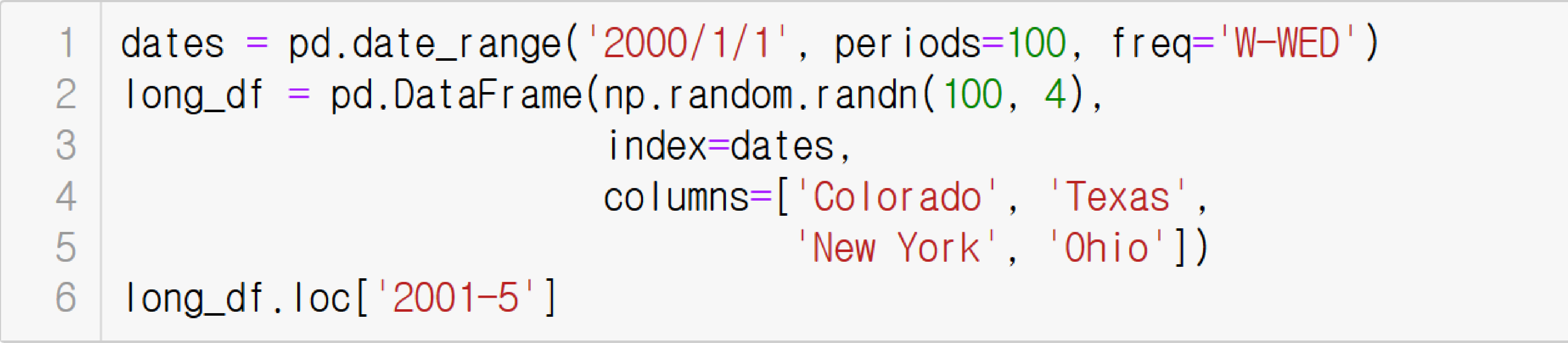
Indexing, Selection, Subsetting



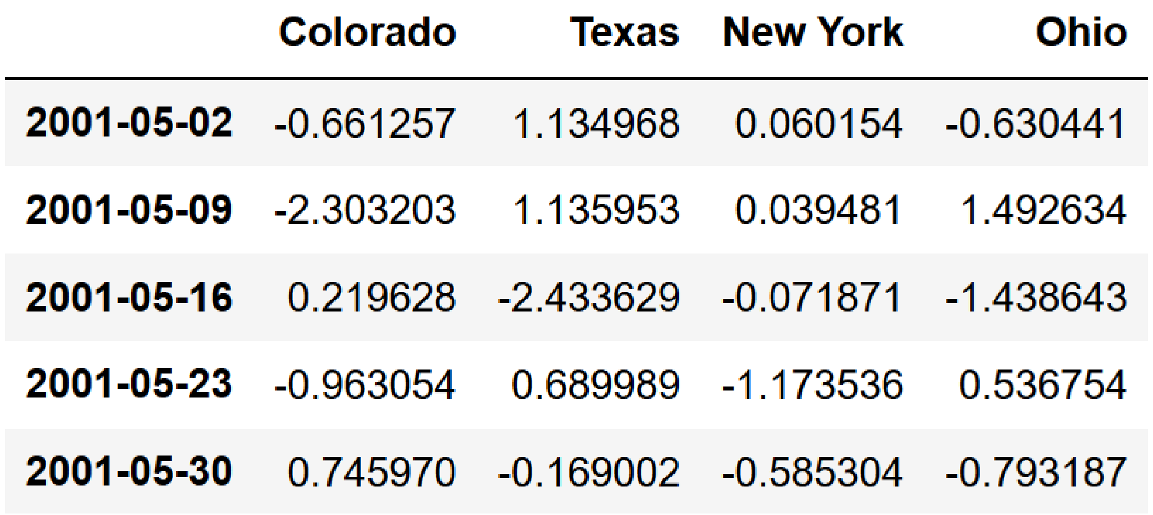
```
ts.truncate(after='2011/1/9')
```

```
2011-01-02   -1.078419
2011-01-05    2.213262
2011-01-07    0.447194
2011-01-08   -0.099447
dtype: float64
```

Indexing, Selection, Subsetting

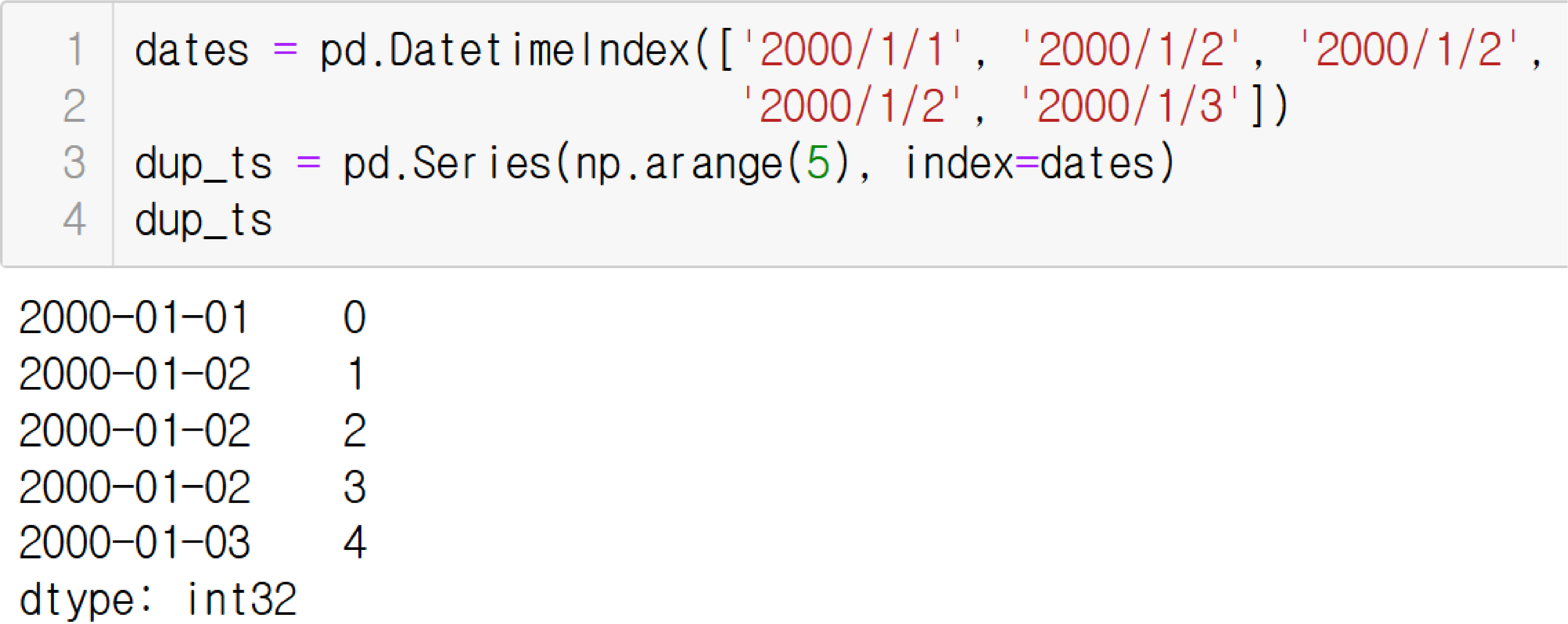


```python
dates = pd.date_range('2000/1/1', periods=100, freq='W-WED')
long_df = pd.DataFrame(np.random.randn(100, 4),
                       index=dates,
                       columns=['Colorado', 'Texas',
                                'New York', 'Ohio'])
long_df.loc['2001-5']
```



```
            Colorado     Texas  New York      Ohio
2001-05-02 -0.661257  1.134968  0.060154 -0.630441
2001-05-09 -2.303203  1.135953  0.039481  1.492634
2001-05-16  0.219628 -2.433629 -0.071871 -1.438643
2001-05-23 -0.963054  0.689989 -1.173536  0.536754
2001-05-30  0.745970 -0.169002 -0.585304 -0.793187
```

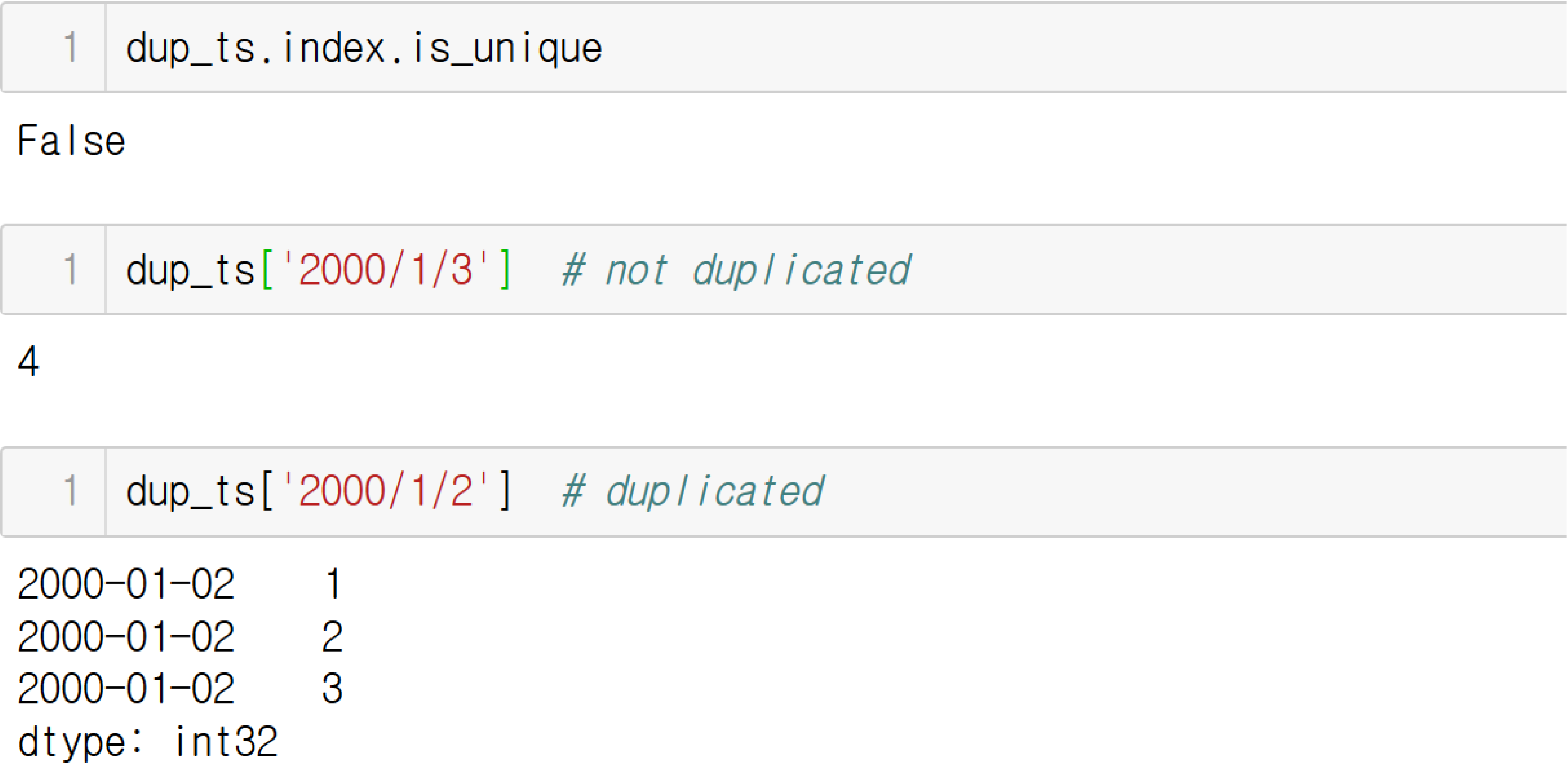
Time Series with Duplicate Indices



```
dates = pd.DatetimeIndex(['2000/1/1', '2000/1/2', '2000/1/2',
                          '2000/1/2', '2000/1/3'])
dup_ts = pd.Series(np.arange(5), index=dates)
dup_ts
```

```
2000-01-01    0
2000-01-02    1
2000-01-02    2
2000-01-02    3
2000-01-03    4
dtype: int32
```

Time Series with Duplicate Indices



```python
dup_ts.index.is_unique
```

```
False
```

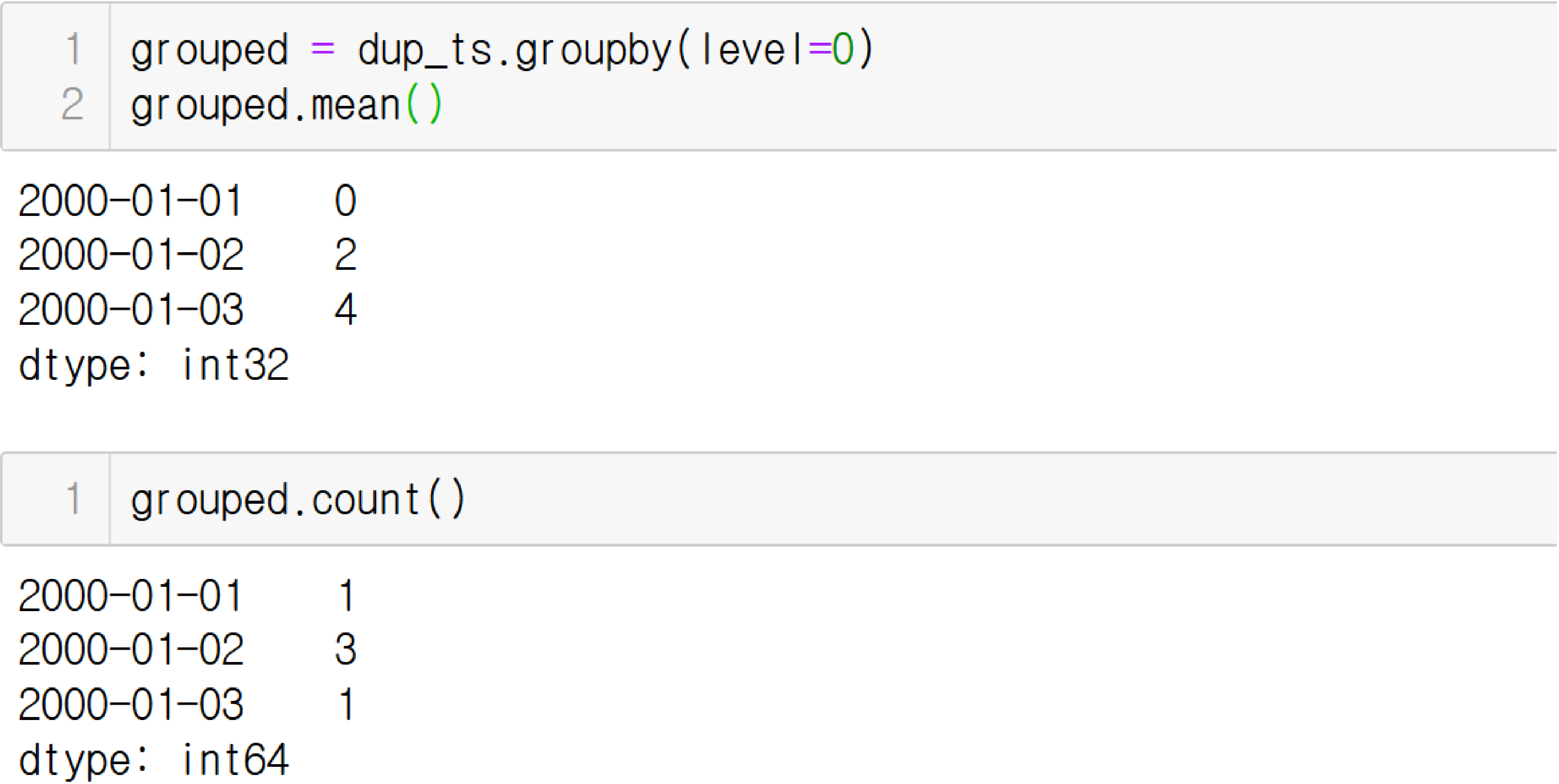
```python
dup_ts['2000/1/3']  # not duplicated
```

```
4
```

```python
dup_ts['2000/1/2']  # duplicated
```

```
2000-01-02    1
2000-01-02    2
2000-01-02    3
dtype: int32
```

Time Series with Duplicate Indices



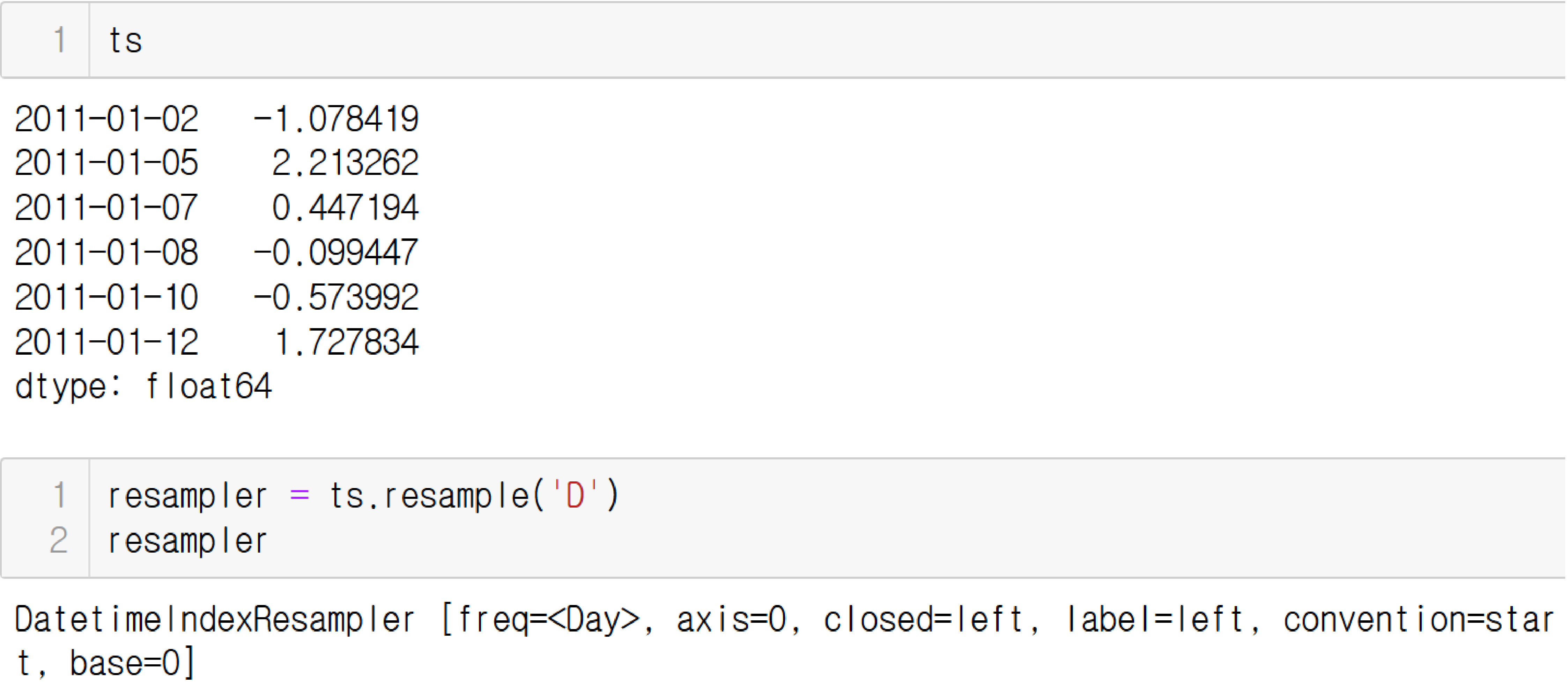
```python
grouped = dup_ts.groupby(level=0)
grouped.mean()
```

```
2000-01-01    0
2000-01-02    2
2000-01-03    4
dtype: int32
```

```python
grouped.count()
```

```
2000-01-01    1
2000-01-02    3
2000-01-03    1
dtype: int64
```

Date Ranges, Frequencies, and Shifting



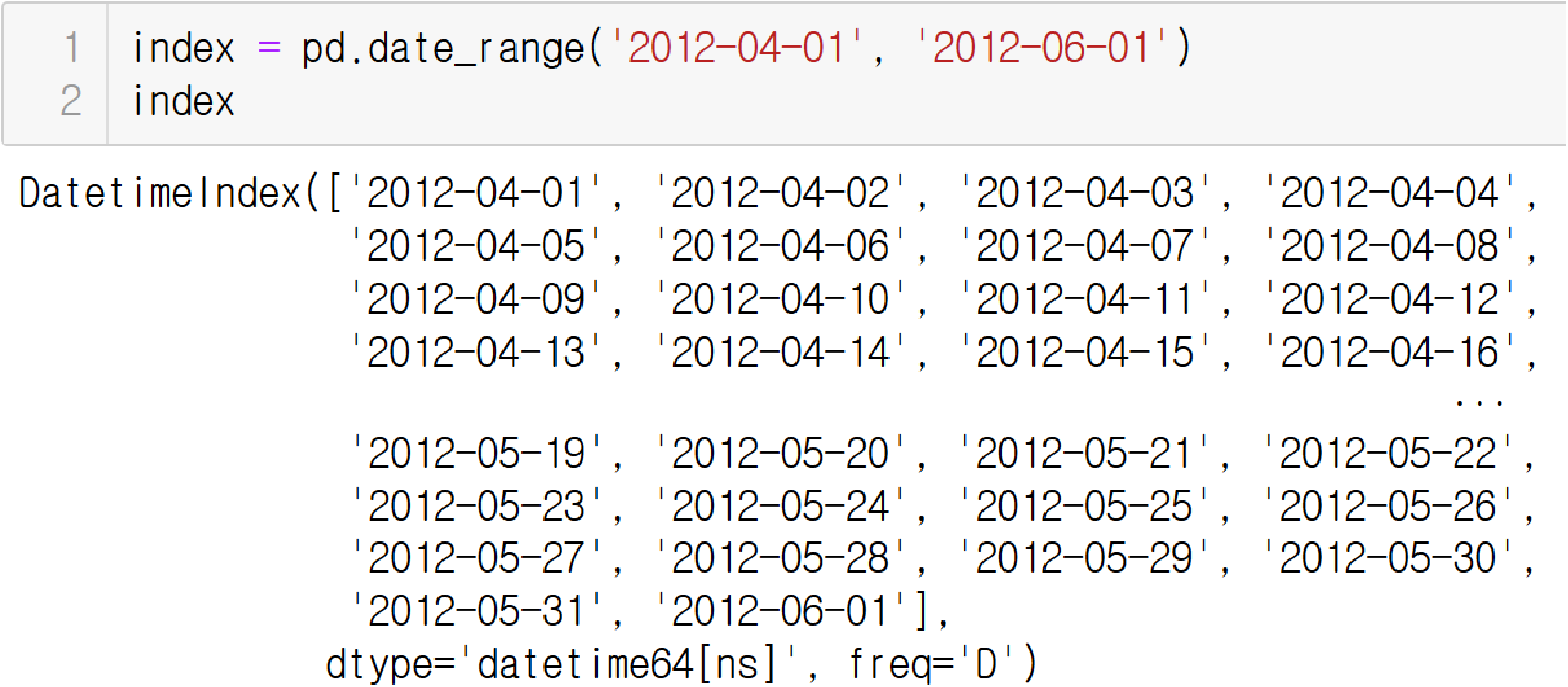
```python
ts
```

```
2011-01-02   -1.078419
2011-01-05    2.213262
2011-01-07    0.447194
2011-01-08   -0.099447
2011-01-10   -0.573992
2011-01-12    1.727834
dtype: float64
```

```python
resampler = ts.resample('D')
resampler
```

```
DatetimeIndexResampler [freq=<Day>, axis=0, closed=left, label=left, convention=star
t, base=0]
```

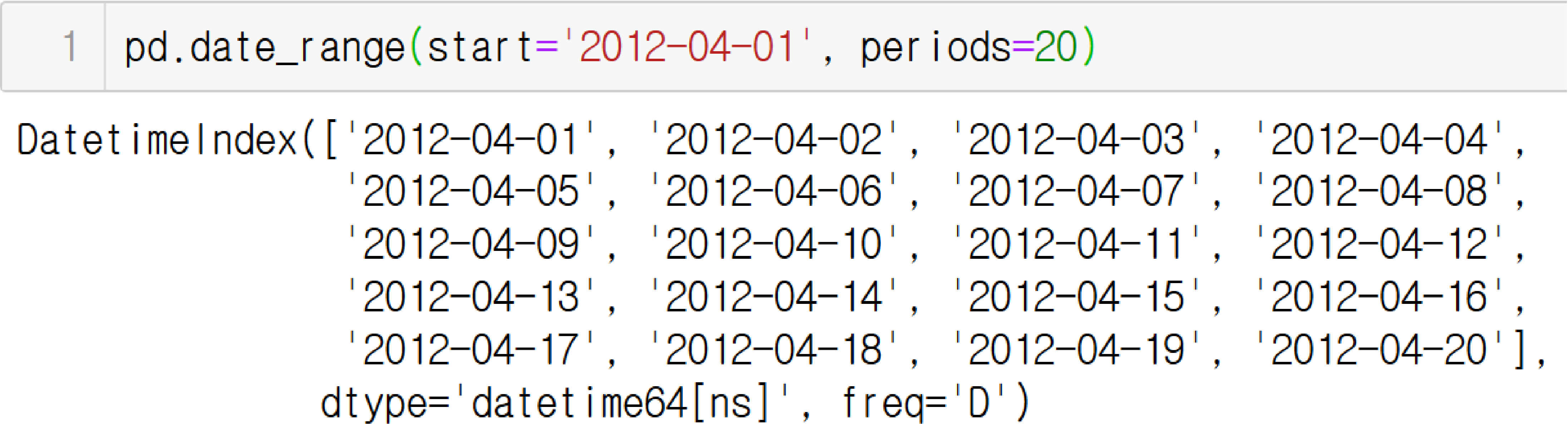
Generating Date Ranges



```
index = pd.date_range('2012-04-01', '2012-06-01')
index
```

```
DatetimeIndex(['2012-04-01', '2012-04-02', '2012-04-03', '2012-04-04',
               '2012-04-05', '2012-04-06', '2012-04-07', '2012-04-08',
               '2012-04-09', '2012-04-10', '2012-04-11', '2012-04-12',
               '2012-04-13', '2012-04-14', '2012-04-15', '2012-04-16',
                                                                 ...
               '2012-05-19', '2012-05-20', '2012-05-21', '2012-05-22',
               '2012-05-23', '2012-05-24', '2012-05-25', '2012-05-26',
               '2012-05-27', '2012-05-28', '2012-05-29', '2012-05-30',
               '2012-05-31', '2012-06-01'],
              dtype='datetime64[ns]', freq='D')
```

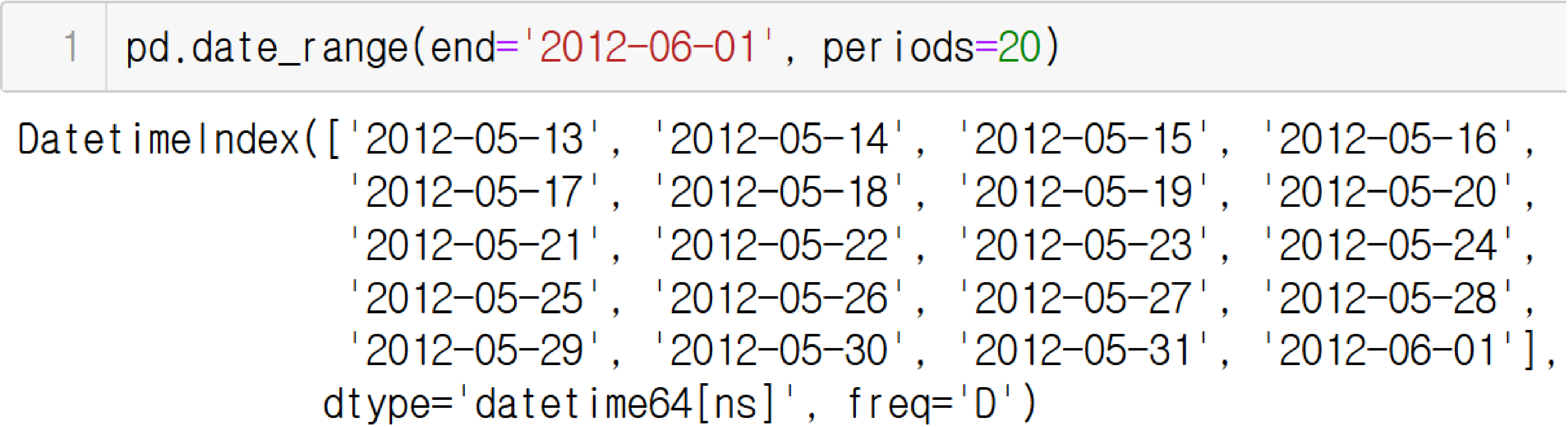
Generating Date Ranges



```
pd.date_range(start='2012-04-01', periods=20)
```

```
DatetimeIndex(['2012-04-01', '2012-04-02', '2012-04-03', '2012-04-04',
               '2012-04-05', '2012-04-06', '2012-04-07', '2012-04-08',
               '2012-04-09', '2012-04-10', '2012-04-11', '2012-04-12',
               '2012-04-13', '2012-04-14', '2012-04-15', '2012-04-16',
               '2012-04-17', '2012-04-18', '2012-04-19', '2012-04-20'],
              dtype='datetime64[ns]', freq='D')
```

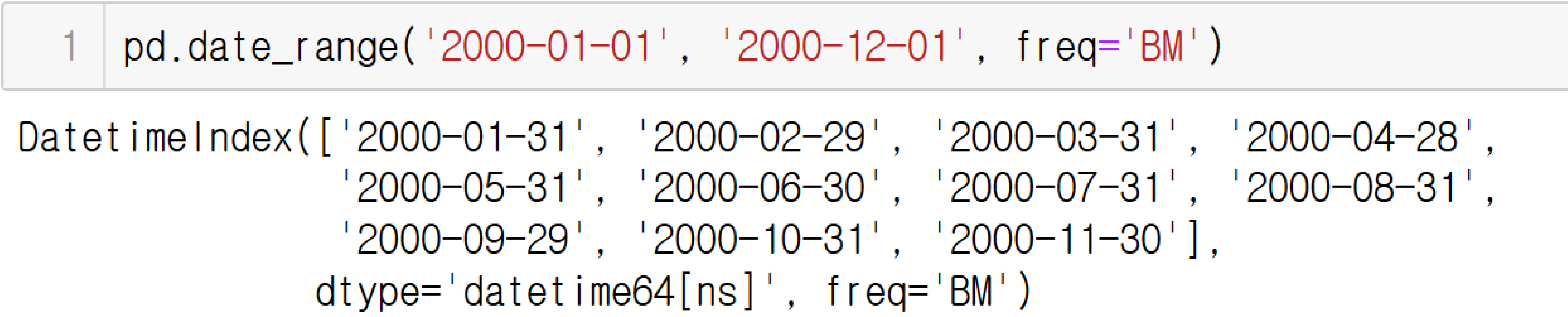
Generating Date Ranges



```python
pd.date_range(end='2012-06-01', periods=20)
```

```
DatetimeIndex(['2012-05-13', '2012-05-14', '2012-05-15', '2012-05-16',
               '2012-05-17', '2012-05-18', '2012-05-19', '2012-05-20',
               '2012-05-21', '2012-05-22', '2012-05-23', '2012-05-24',
               '2012-05-25', '2012-05-26', '2012-05-27', '2012-05-28',
               '2012-05-29', '2012-05-30', '2012-05-31', '2012-06-01'],
              dtype='datetime64[ns]', freq='D')
```

Generating Date Ranges

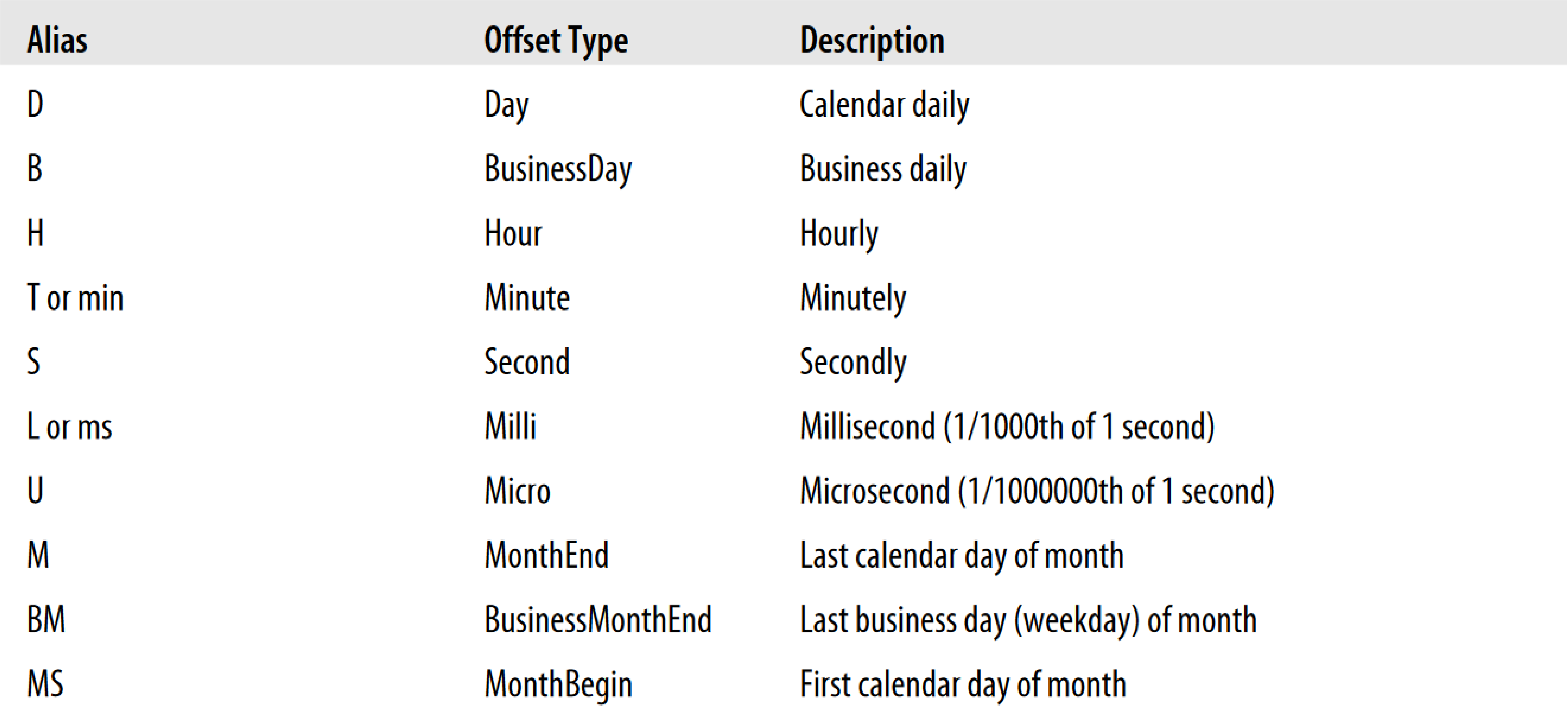


```
pd.date_range('2000-01-01', '2000-12-01', freq='BM')
```

```
DatetimeIndex(['2000-01-31', '2000-02-29', '2000-03-31', '2000-04-28',
               '2000-05-31', '2000-06-30', '2000-07-31', '2000-08-31',
               '2000-09-29', '2000-10-31', '2000-11-30'],
              dtype='datetime64[ns]', freq='BM')
```

Generating Date Ranges

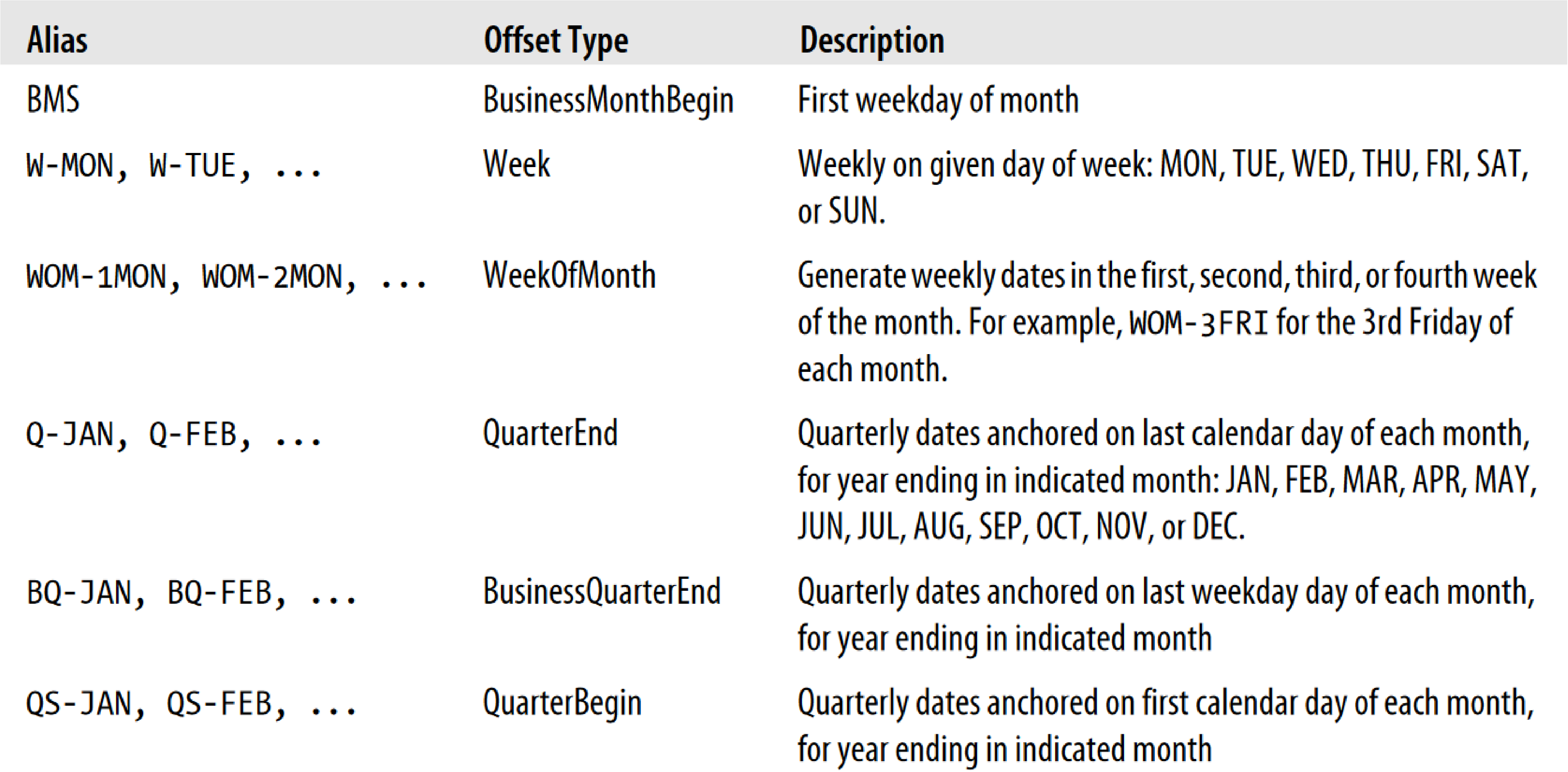
Base Time Series Frequencies



Alias	Offset Type	Description
D	Day	Calendar daily
B	BusinessDay	Business daily
H	Hour	Hourly
T or min	Minute	Minutely
S	Second	Secondly
L or ms	Milli	Millisecond (1/1000th of 1 second)
U	Micro	Microsecond (1/1000000th of 1 second)
M	MonthEnd	Last calendar day of month
BM	BusinessMonthEnd	Last business day (weekday) of month
MS	MonthBegin	First calendar day of month

Generating Date Ranges

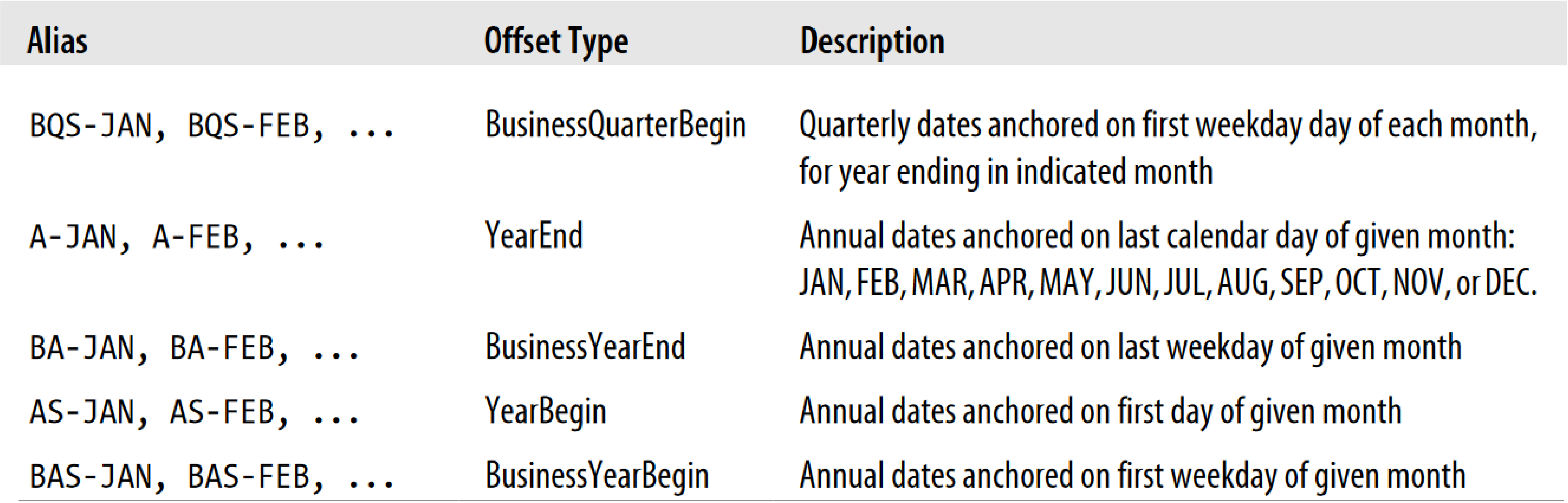
Base Time Series Frequencies



Alias	Offset Type	Description
BMS	BusinessMonthBegin	First weekday of month
`W-MON, W-TUE, ...`	Week	Weekly on given day of week: MON, TUE, WED, THU, FRI, SAT, or SUN.
`WOM-1MON, WOM-2MON, ...`	WeekOfMonth	Generate weekly dates in the first, second, third, or fourth week of the month. For example, `WOM-3FRI` for the 3rd Friday of each month.
`Q-JAN, Q-FEB, ...`	QuarterEnd	Quarterly dates anchored on last calendar day of each month, for year ending in indicated month: JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, or DEC.
`BQ-JAN, BQ-FEB, ...`	BusinessQuarterEnd	Quarterly dates anchored on last weekday day of each month, for year ending in indicated month
`QS-JAN, QS-FEB, ...`	QuarterBegin	Quarterly dates anchored on first calendar day of each month, for year ending in indicated month

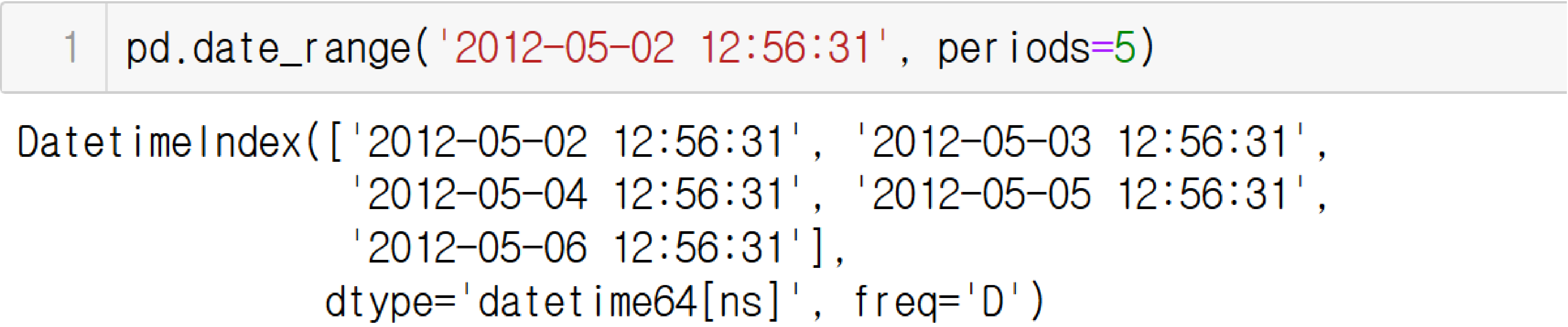
Generating Date Ranges

Base Time Series Frequencies



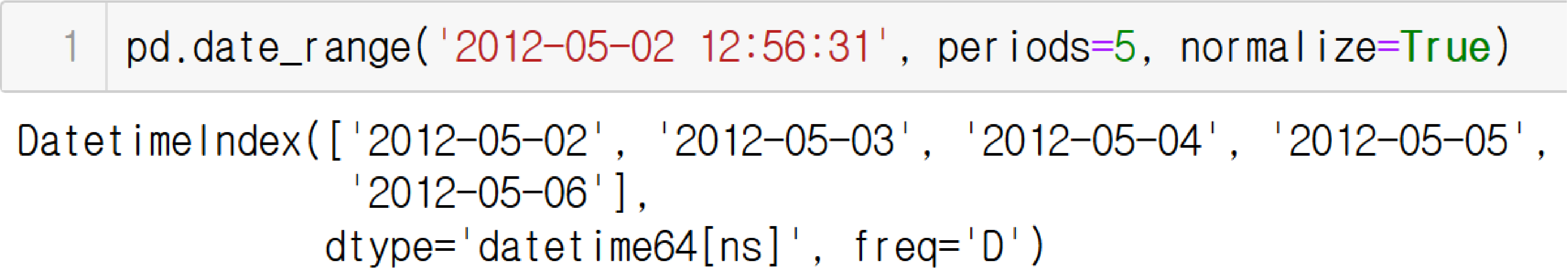
Alias	Offset Type	Description
`BQS-JAN, BQS-FEB, ...`	BusinessQuarterBegin	Quarterly dates anchored on first weekday day of each month, for year ending in indicated month
`A-JAN, A-FEB, ...`	YearEnd	Annual dates anchored on last calendar day of given month: JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, or DEC.
`BA-JAN, BA-FEB, ...`	BusinessYearEnd	Annual dates anchored on last weekday of given month
`AS-JAN, AS-FEB, ...`	YearBegin	Annual dates anchored on first day of given month
`BAS-JAN, BAS-FEB, ...`	BusinessYearBegin	Annual dates anchored on first weekday of given month

Generating Date Ranges



```python
pd.date_range('2012-05-02 12:56:31', periods=5)
```

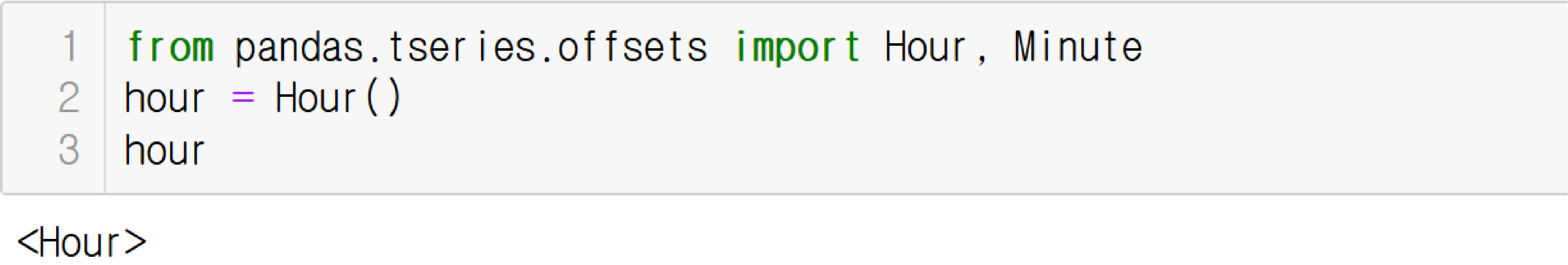
```
DatetimeIndex(['2012-05-02 12:56:31', '2012-05-03 12:56:31',
               '2012-05-04 12:56:31', '2012-05-05 12:56:31',
               '2012-05-06 12:56:31'],
              dtype='datetime64[ns]', freq='D')
```



```python
pd.date_range('2012-05-02 12:56:31', periods=5, normalize=True)
```

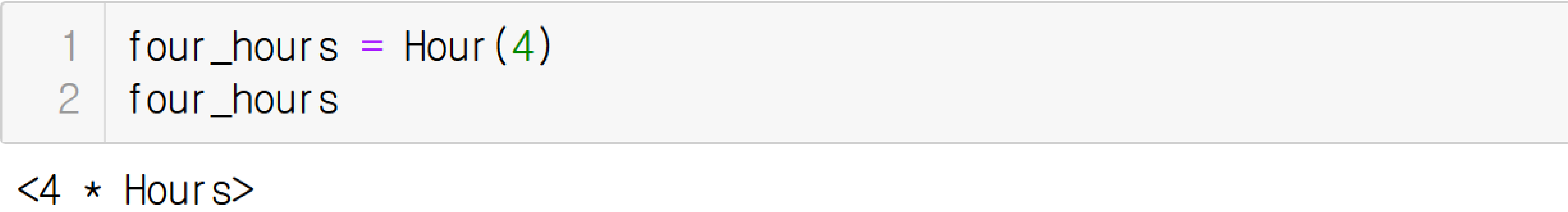
```
DatetimeIndex(['2012-05-02', '2012-05-03', '2012-05-04', '2012-05-05',
               '2012-05-06'],
              dtype='datetime64[ns]', freq='D')
```

Frequencies and Date Offsets



```python
from pandas.tseries.offsets import Hour, Minute
hour = Hour()
hour
```

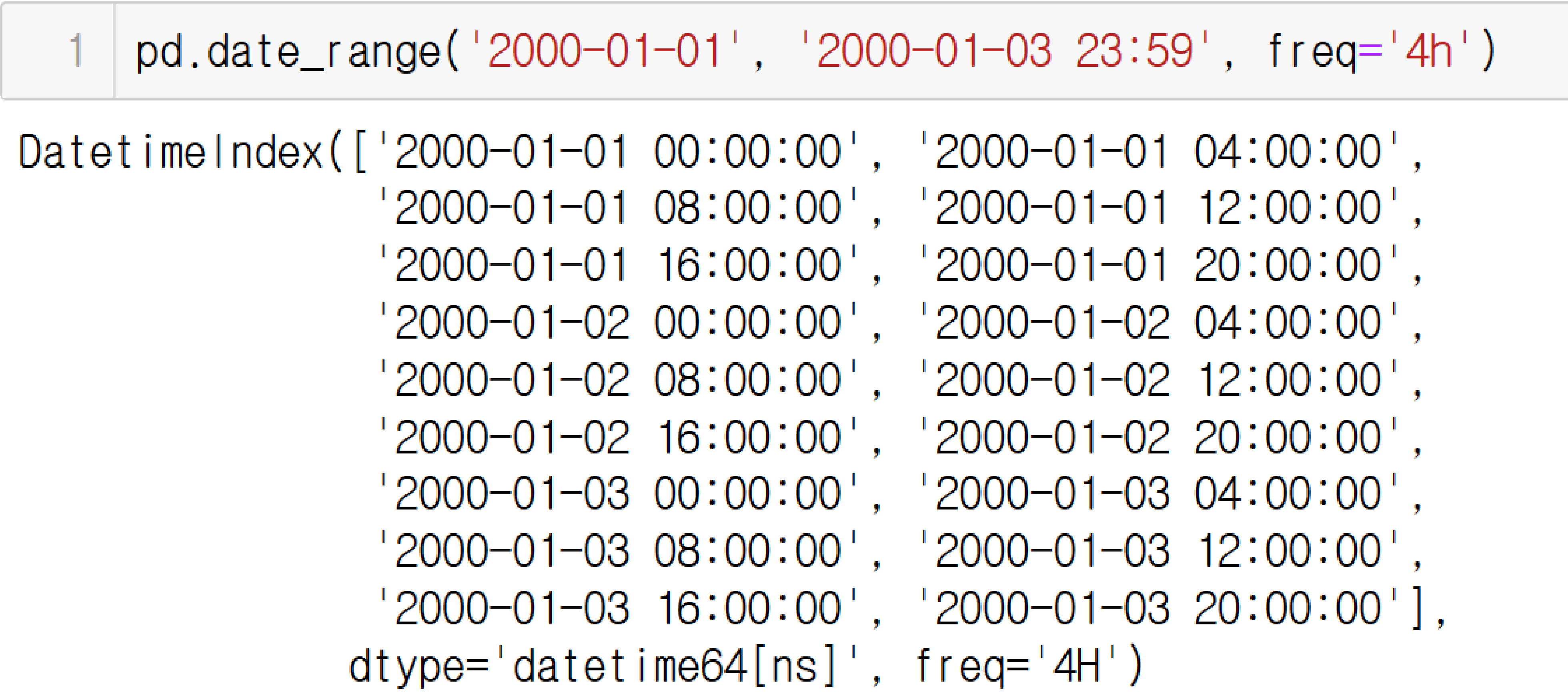
```
<Hour>
```



```python
four_hours = Hour(4)
four_hours
```

```
<4 * Hours>
```

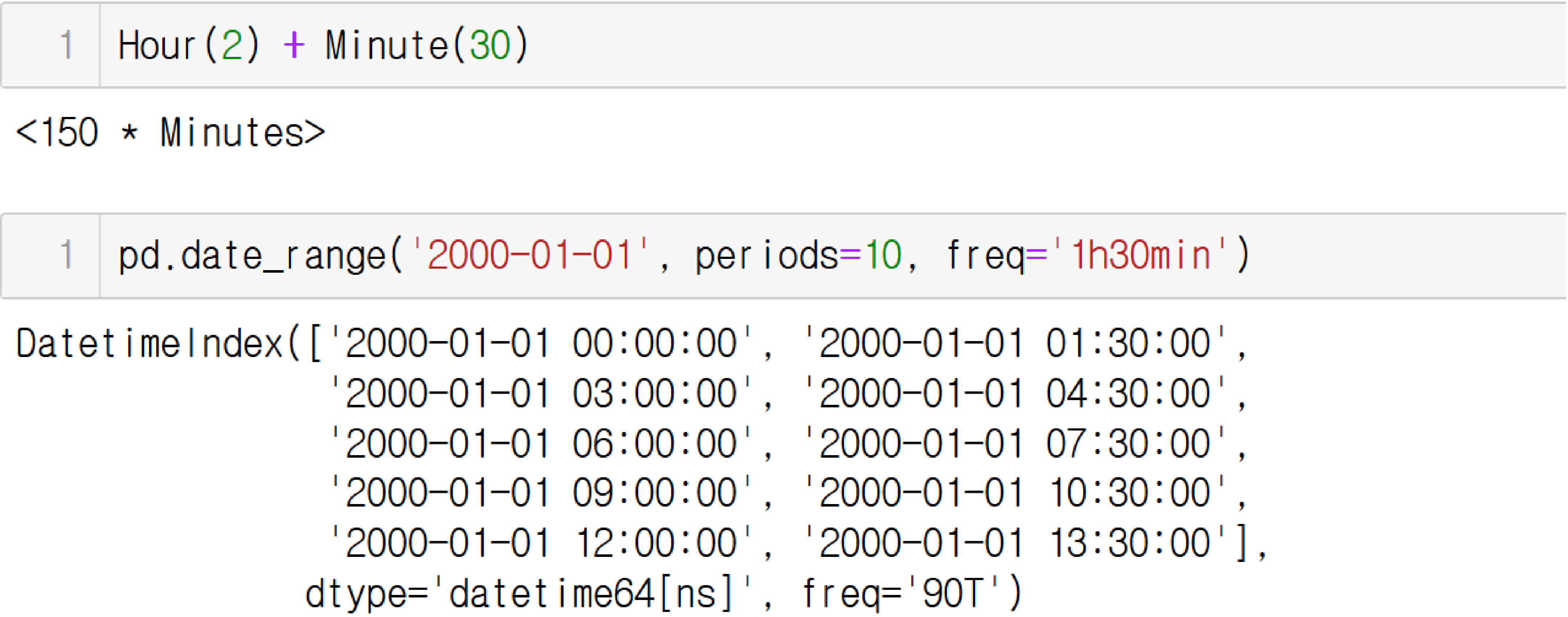
Frequencies and Date Offsets



```python
pd.date_range('2000-01-01', '2000-01-03 23:59', freq='4h')
```

```
DatetimeIndex(['2000-01-01 00:00:00', '2000-01-01 04:00:00',
               '2000-01-01 08:00:00', '2000-01-01 12:00:00',
               '2000-01-01 16:00:00', '2000-01-01 20:00:00',
               '2000-01-02 00:00:00', '2000-01-02 04:00:00',
               '2000-01-02 08:00:00', '2000-01-02 12:00:00',
               '2000-01-02 16:00:00', '2000-01-02 20:00:00',
               '2000-01-03 00:00:00', '2000-01-03 04:00:00',
               '2000-01-03 08:00:00', '2000-01-03 12:00:00',
               '2000-01-03 16:00:00', '2000-01-03 20:00:00'],
              dtype='datetime64[ns]', freq='4H')
```

Frequencies and Date Offsets



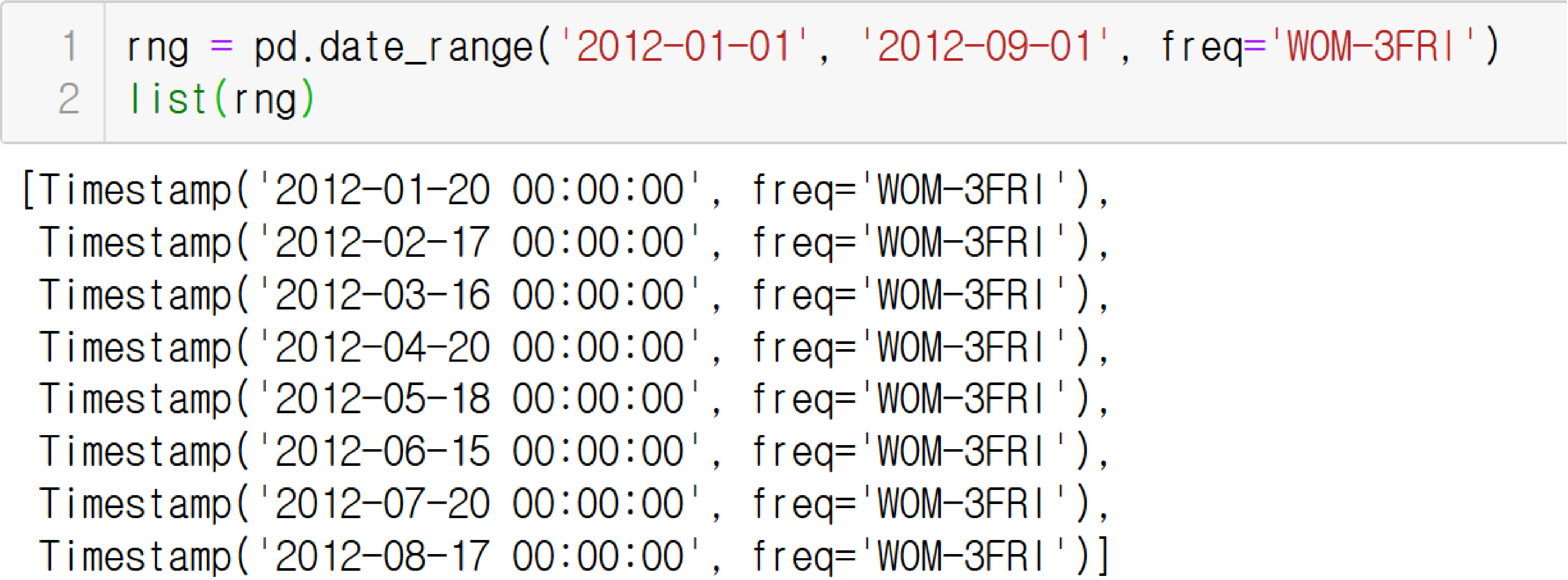
```python
Hour(2) + Minute(30)
```

```
<150 * Minutes>
```

```python
pd.date_range('2000-01-01', periods=10, freq='1h30min')
```

```
DatetimeIndex(['2000-01-01 00:00:00', '2000-01-01 01:30:00',
               '2000-01-01 03:00:00', '2000-01-01 04:30:00',
               '2000-01-01 06:00:00', '2000-01-01 07:30:00',
               '2000-01-01 09:00:00', '2000-01-01 10:30:00',
               '2000-01-01 12:00:00', '2000-01-01 13:30:00'],
              dtype='datetime64[ns]', freq='90T')
```

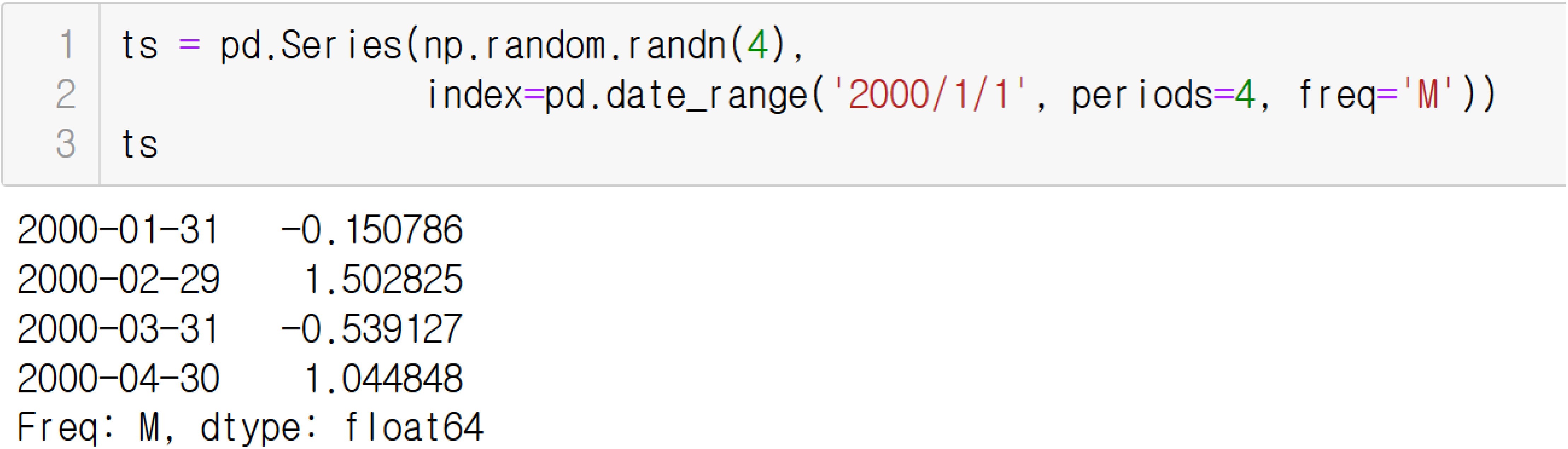
Week of month dates



```
rng = pd.date_range('2012-01-01', '2012-09-01', freq='WOM-3FRI')
list(rng)
```

```
[Timestamp('2012-01-20 00:00:00', freq='WOM-3FRI'),
 Timestamp('2012-02-17 00:00:00', freq='WOM-3FRI'),
 Timestamp('2012-03-16 00:00:00', freq='WOM-3FRI'),
 Timestamp('2012-04-20 00:00:00', freq='WOM-3FRI'),
 Timestamp('2012-05-18 00:00:00', freq='WOM-3FRI'),
 Timestamp('2012-06-15 00:00:00', freq='WOM-3FRI'),
 Timestamp('2012-07-20 00:00:00', freq='WOM-3FRI'),
 Timestamp('2012-08-17 00:00:00', freq='WOM-3FRI')]
```

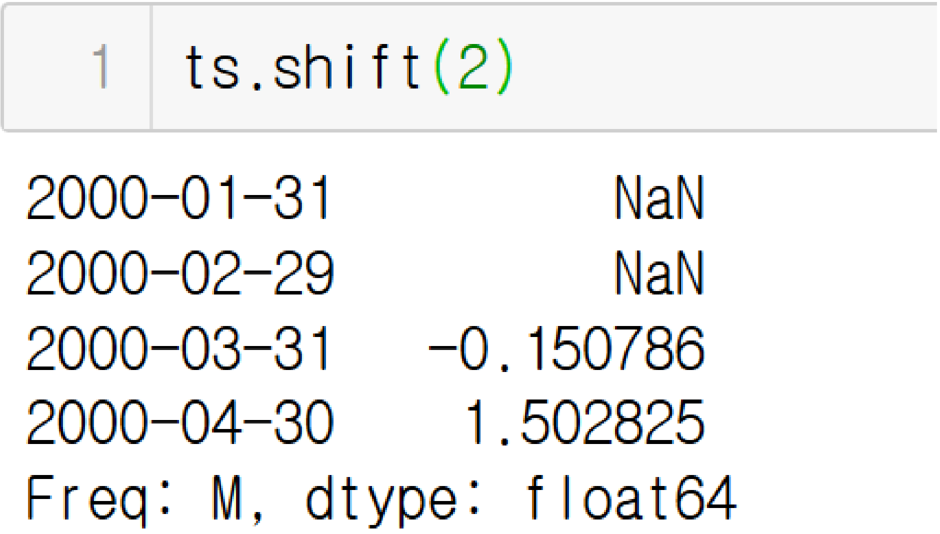
Shifting (Leading and Lagging) Data



```
ts = pd.Series(np.random.randn(4),
               index=pd.date_range('2000/1/1', periods=4, freq='M'))
ts
```

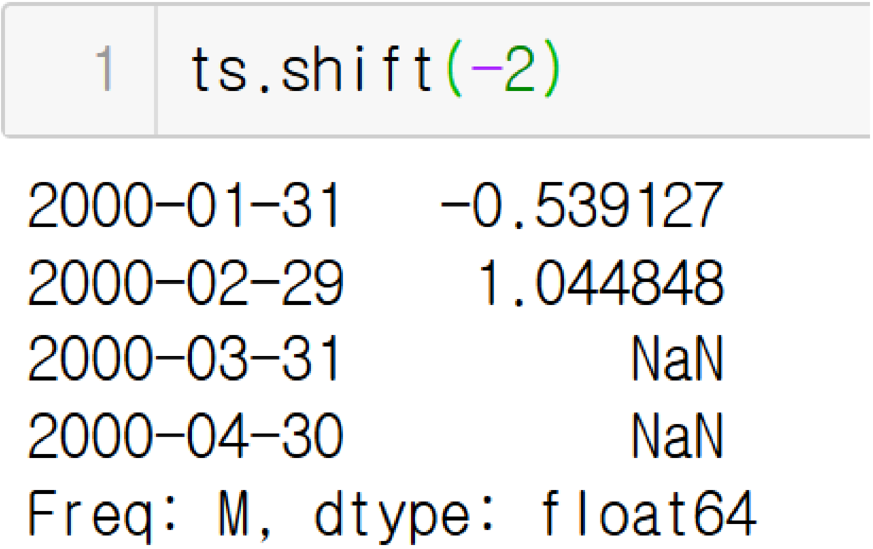
```
2000-01-31   -0.150786
2000-02-29    1.502825
2000-03-31   -0.539127
2000-04-30    1.044848
Freq: M, dtype: float64
```

Shifting (Leading and Lagging) Data



```
ts.shift(2)
```

```
2000-01-31          NaN
2000-02-29          NaN
2000-03-31    -0.150786
2000-04-30     1.502825
Freq: M, dtype: float64
```



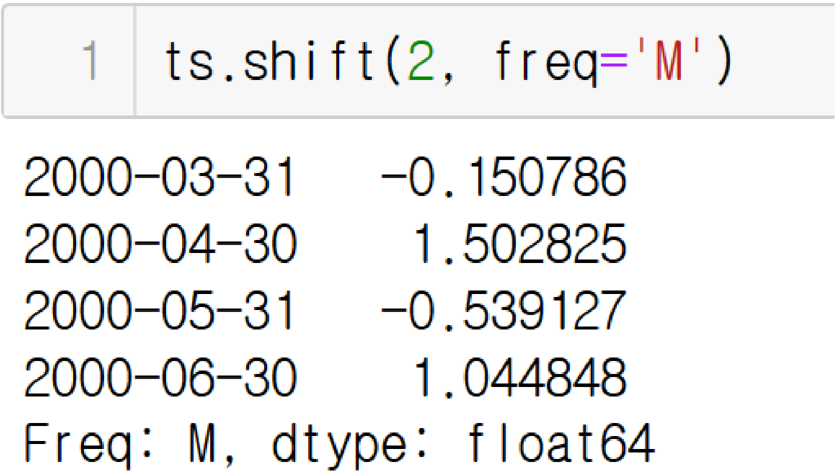
```
ts.shift(-2)
```

```
2000-01-31    -0.539127
2000-02-29     1.044848
2000-03-31          NaN
2000-04-30          NaN
Freq: M, dtype: float64
```

computing percent changes in a time series or multiple timeseries as DataFrame columns.

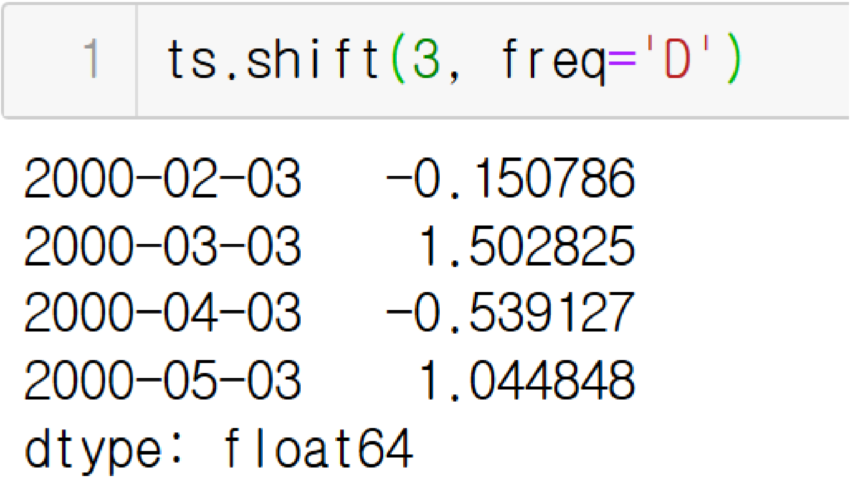
```
ts / ts.shift(1) - 1
```

Shifting (Leading and Lagging) Data



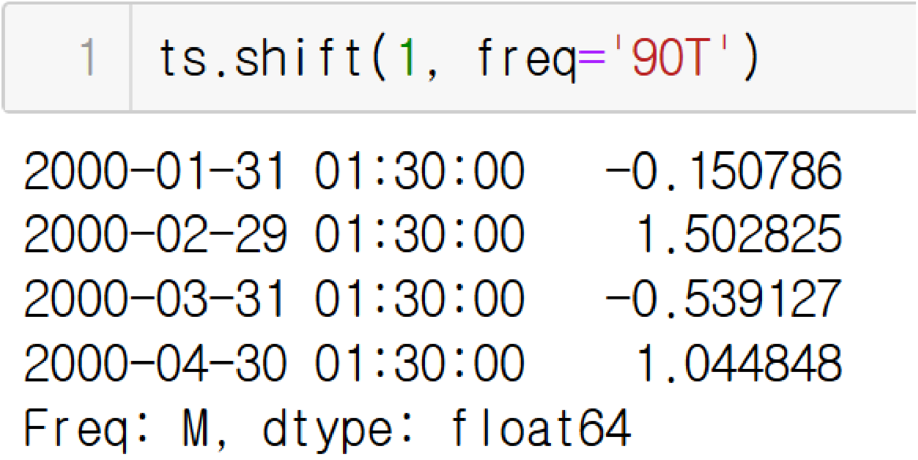
```
ts.shift(2, freq='M')
```

```
2000-03-31   -0.150786
2000-04-30    1.502825
2000-05-31   -0.539127
2000-06-30    1.044848
Freq: M, dtype: float64
```



```
ts.shift(3, freq='D')
```

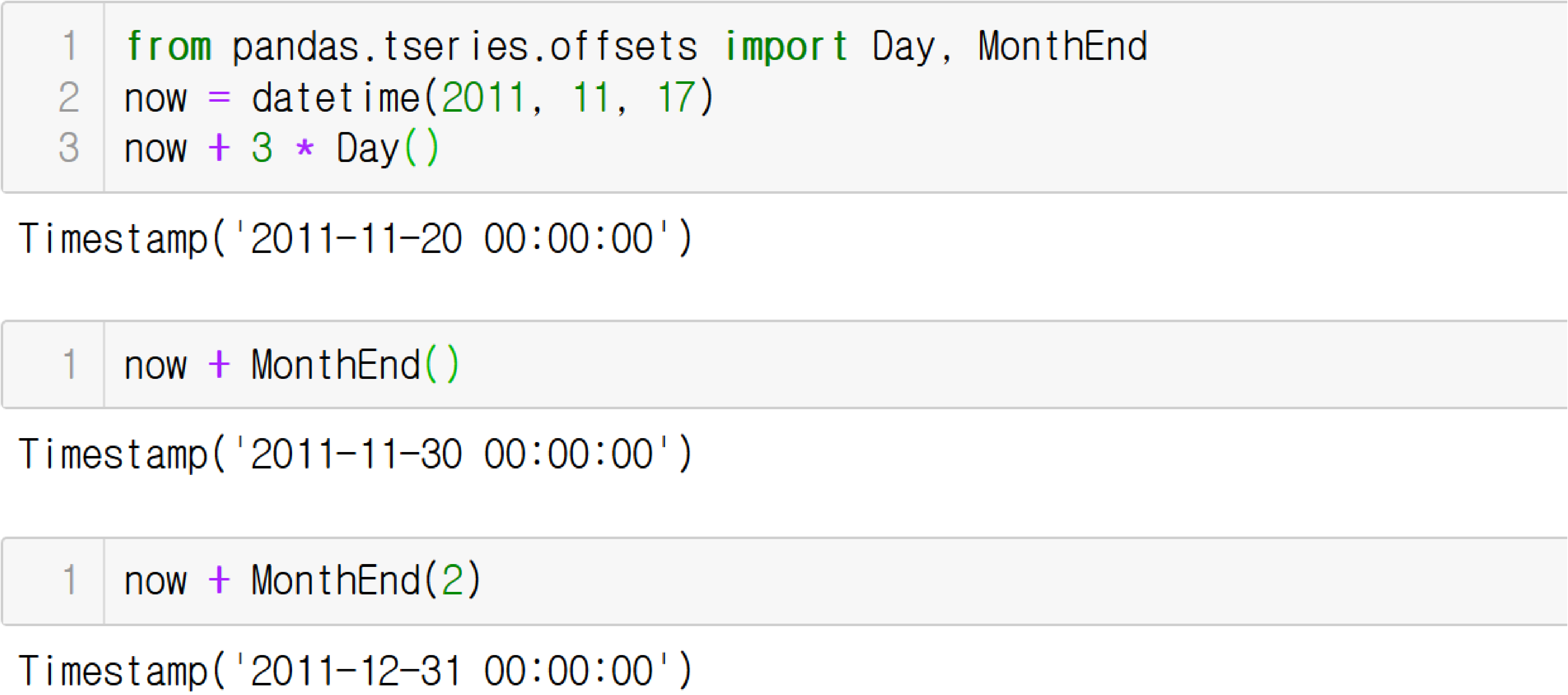
```
2000-02-03   -0.150786
2000-03-03    1.502825
2000-04-03   -0.539127
2000-05-03    1.044848
dtype: float64
```



```
ts.shift(1, freq='90T')
```

```
2000-01-31 01:30:00   -0.150786
2000-02-29 01:30:00    1.502825
2000-03-31 01:30:00   -0.539127
2000-04-30 01:30:00    1.044848
Freq: M, dtype: float64
```

Shifting dates with offsets



```
from pandas.tseries.offsets import Day, MonthEnd
now = datetime(2011, 11, 17)
now + 3 * Day()
```

```
Timestamp('2011-11-20 00:00:00')
```

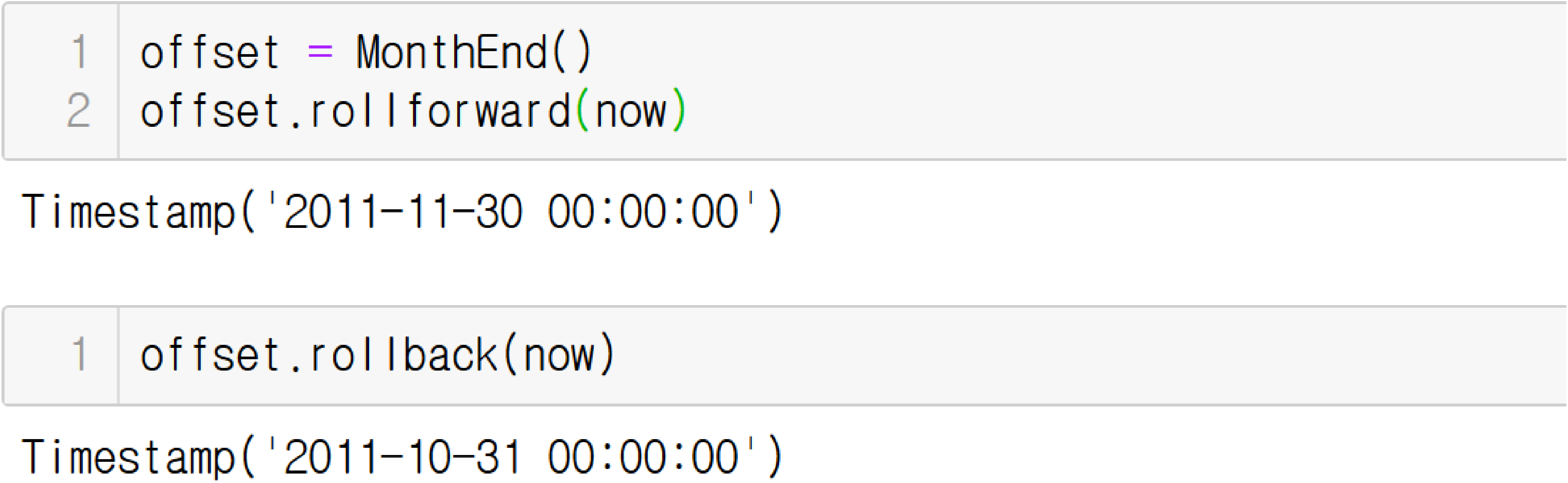
```
now + MonthEnd()
```

```
Timestamp('2011-11-30 00:00:00')
```

```
now + MonthEnd(2)
```

```
Timestamp('2011-12-31 00:00:00')
```

Shifting dates with offsets



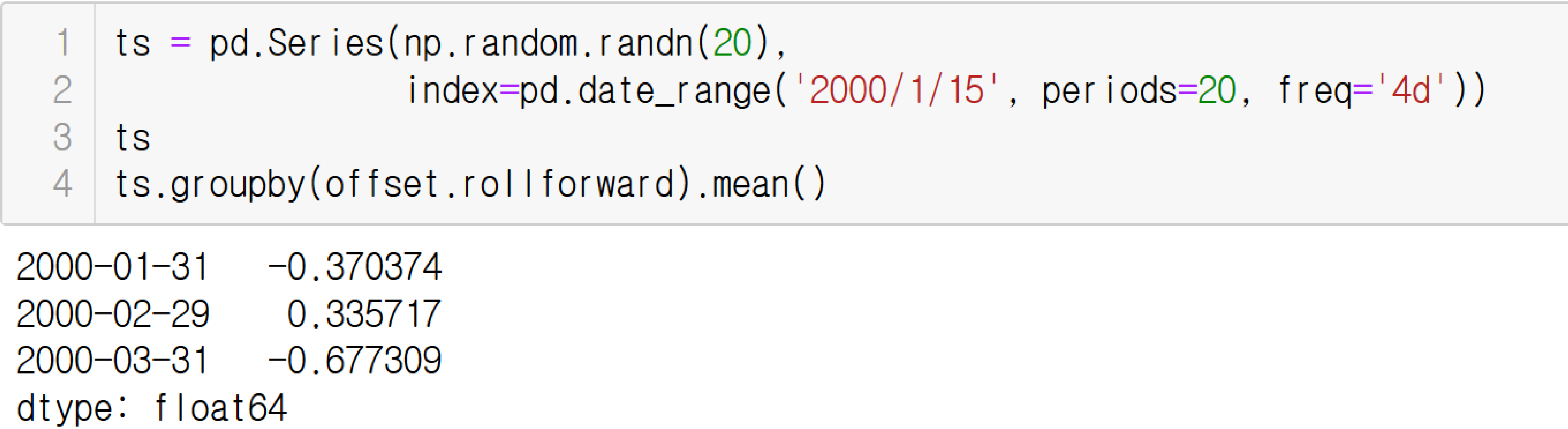
```python
offset = MonthEnd()
offset.rollforward(now)
```

```
Timestamp('2011-11-30 00:00:00')
```

```python
offset.rollback(now)
```

```
Timestamp('2011-10-31 00:00:00')
```

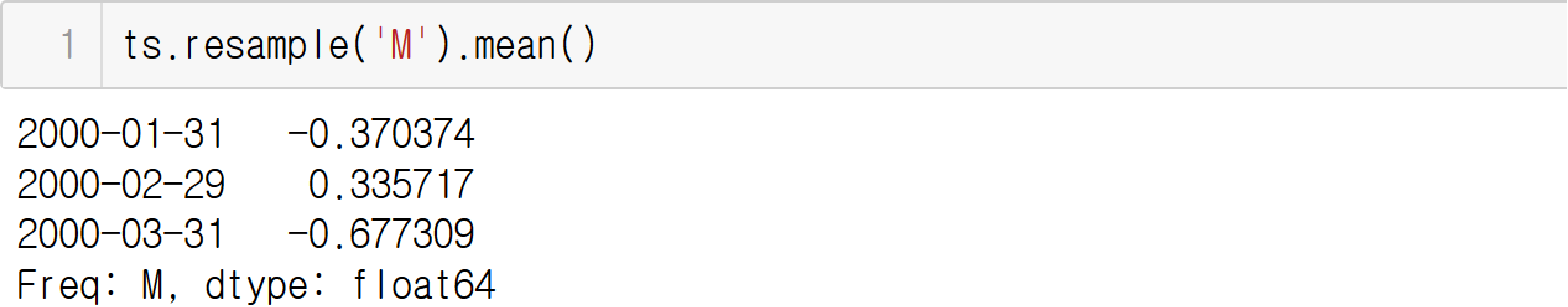
Shifting dates with offsets



```python
ts = pd.Series(np.random.randn(20),
               index=pd.date_range('2000/1/15', periods=20, freq='4d'))
ts
ts.groupby(offset.rollforward).mean()
```

```
2000-01-31   -0.370374
2000-02-29    0.335717
2000-03-31   -0.677309
dtype: float64
```

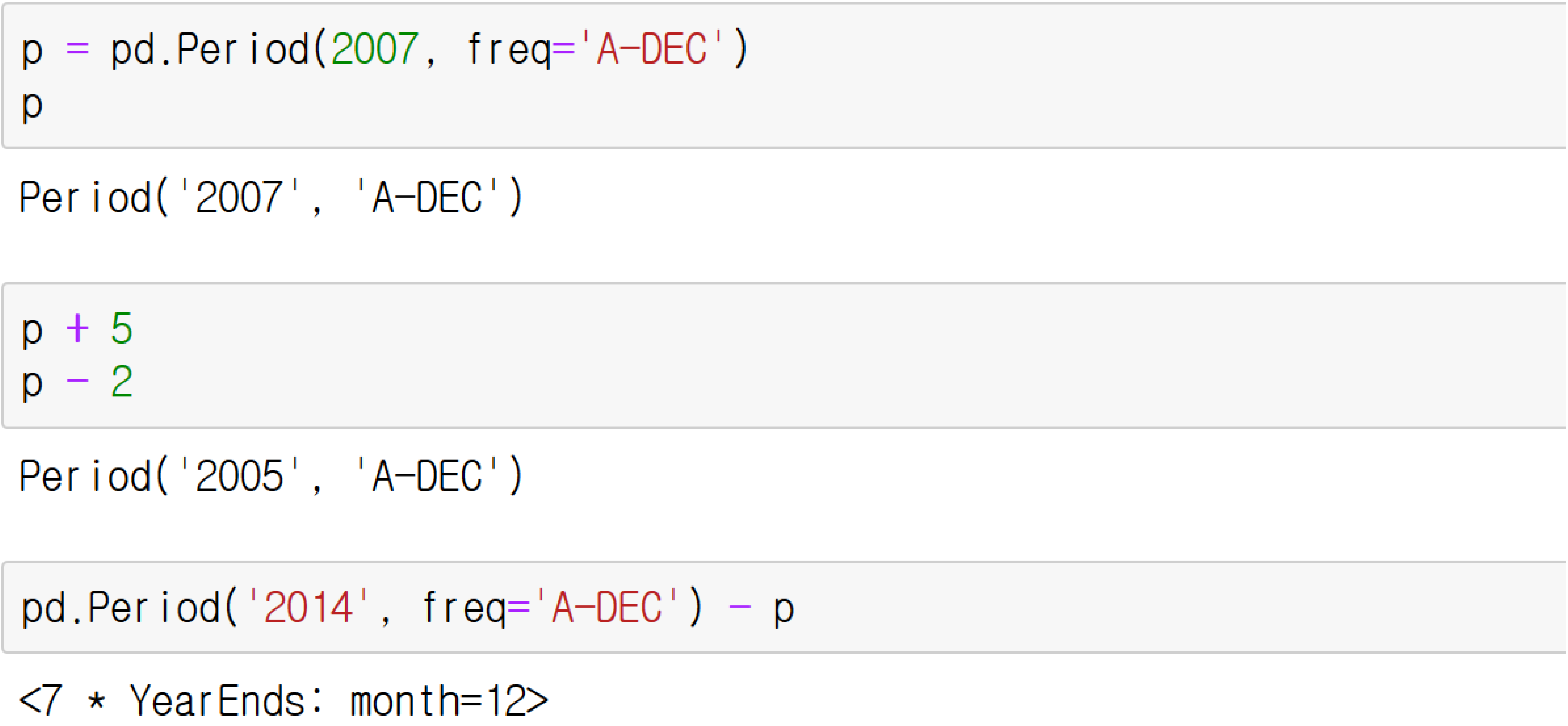
Shifting dates with offsets



```python
ts.resample('M').mean()
```

```
2000-01-31   -0.370374
2000-02-29    0.335717
2000-03-31   -0.677309
Freq: M, dtype: float64
```

Periods and Period Arithmetic



```
p = pd.Period(2007, freq='A-DEC')
p
```

```
Period('2007', 'A-DEC')
```

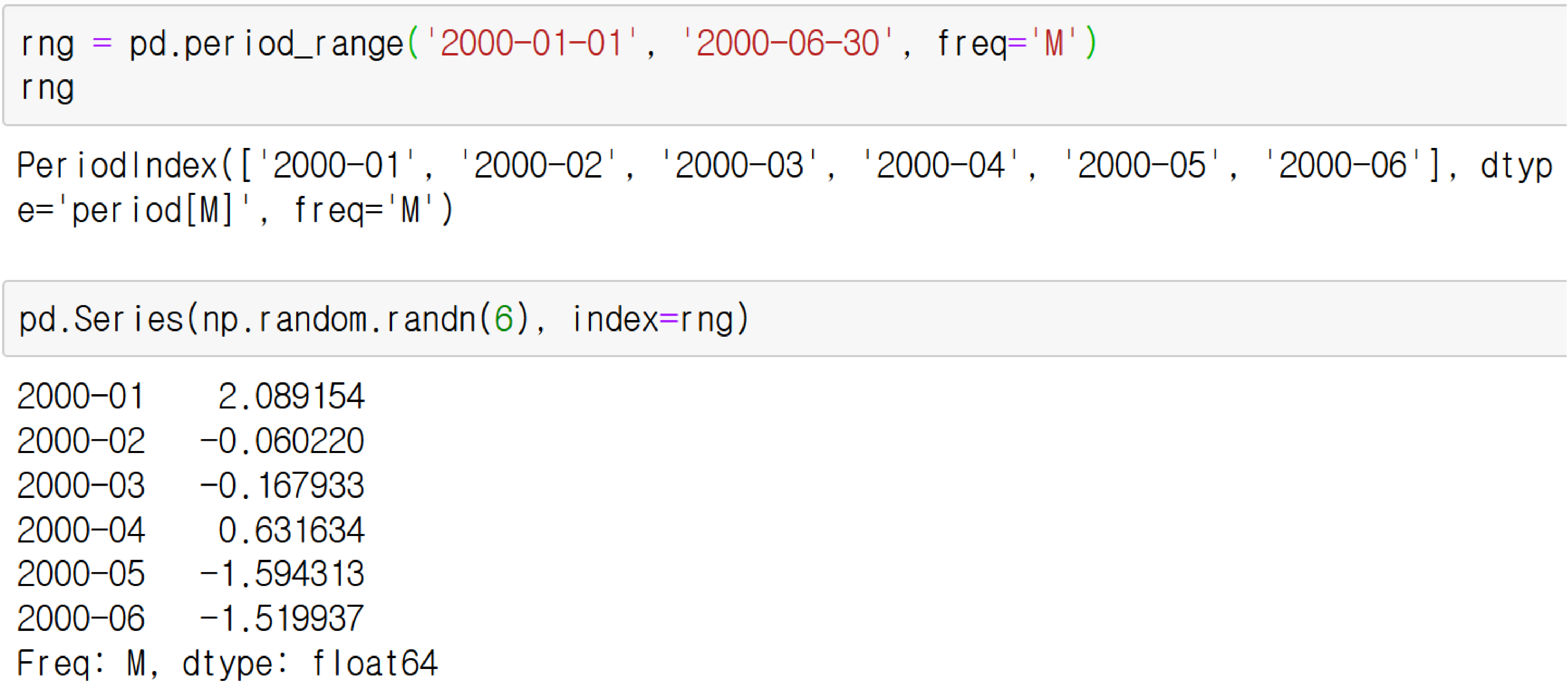
```
p + 5
p - 2
```

```
Period('2005', 'A-DEC')
```

```
pd.Period('2014', freq='A-DEC') - p
```

```
<7 * YearEnds: month=12>
```

Periods and Period Arithmetic



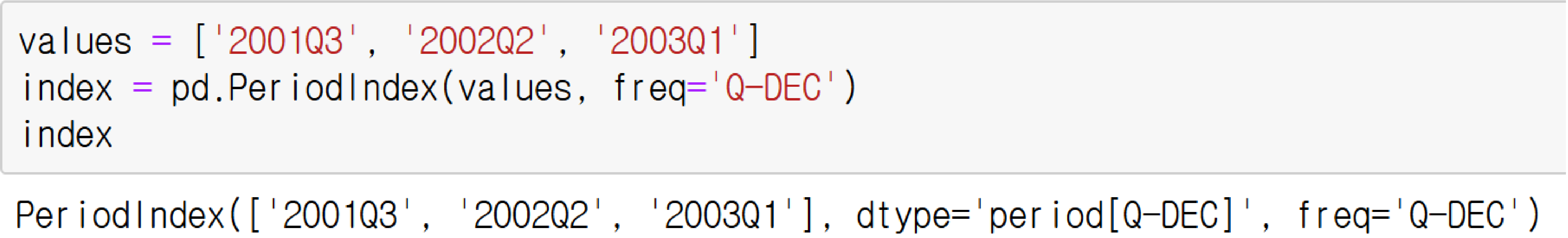
```
rng = pd.period_range('2000-01-01', '2000-06-30', freq='M')
rng
```

```
PeriodIndex(['2000-01', '2000-02', '2000-03', '2000-04', '2000-05', '2000-06'], dtyp
e='period[M]', freq='M')
```

```
pd.Series(np.random.randn(6), index=rng)
```

```
2000-01    2.089154
2000-02   -0.060220
2000-03   -0.167933
2000-04    0.631634
2000-05   -1.594313
2000-06   -1.519937
Freq: M, dtype: float64
```

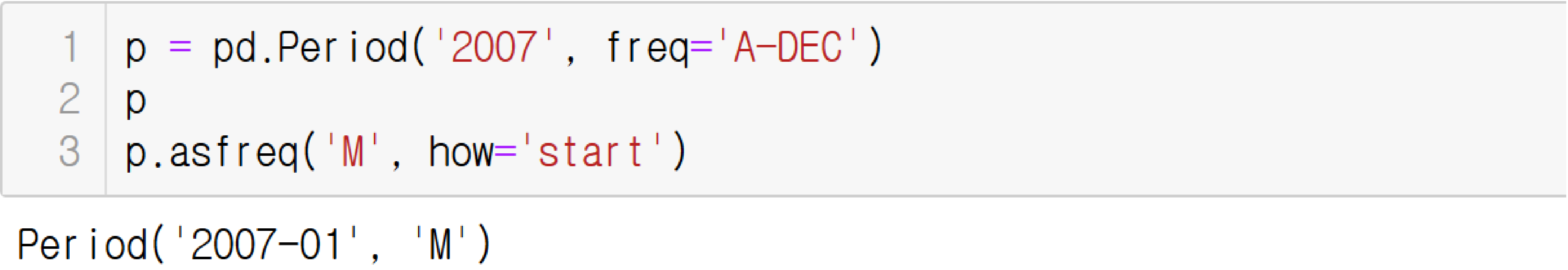
Periods and Period Arithmetic



```
values = ['2001Q3', '2002Q2', '2003Q1']
index = pd.PeriodIndex(values, freq='Q-DEC')
index
```

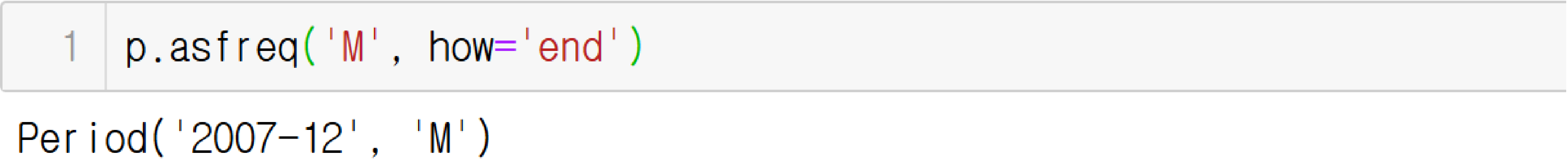
```
PeriodIndex(['2001Q3', '2002Q2', '2003Q1'], dtype='period[Q-DEC]', freq='Q-DEC')
```

Period Frequency Conversion



```python
p = pd.Period('2007', freq='A-DEC')
p
p.asfreq('M', how='start')
```

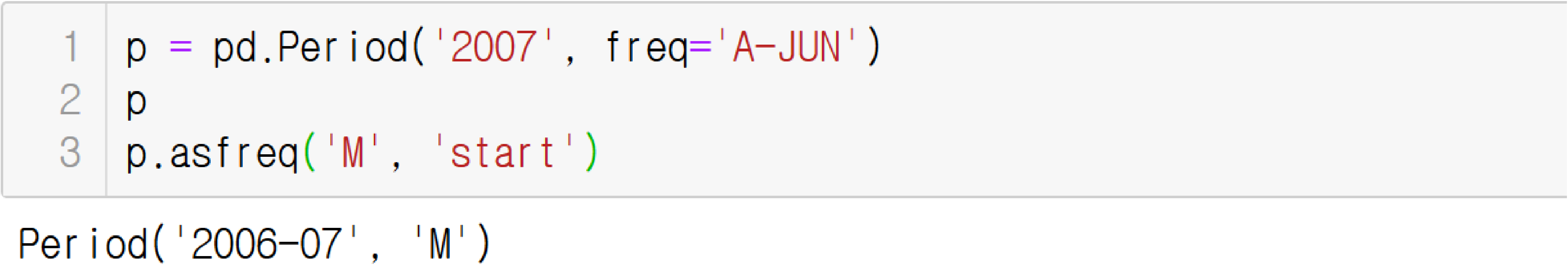
```
Period('2007-01', 'M')
```



```python
p.asfreq('M', how='end')
```

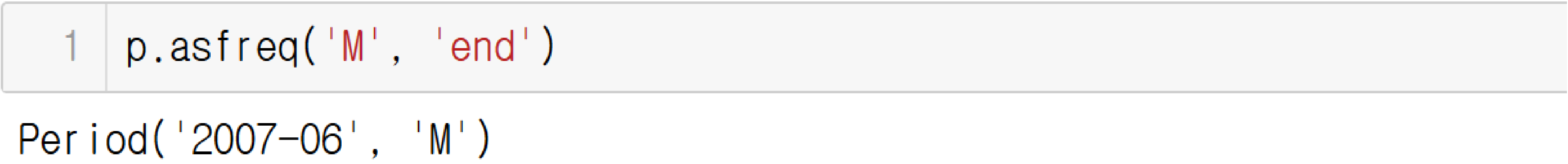
```
Period('2007-12', 'M')
```

Period Frequency Conversion



```
p = pd.Period('2007', freq='A-JUN')
p
p.asfreq('M', 'start')
```

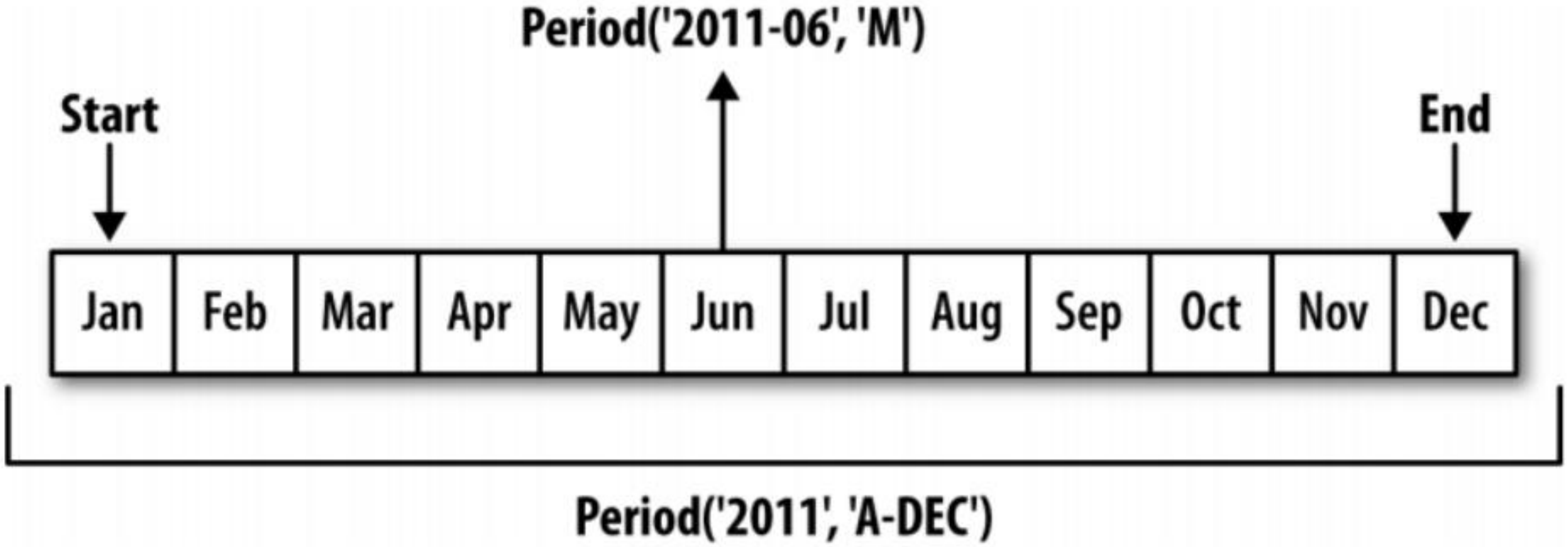
```
Period('2006-07', 'M')
```



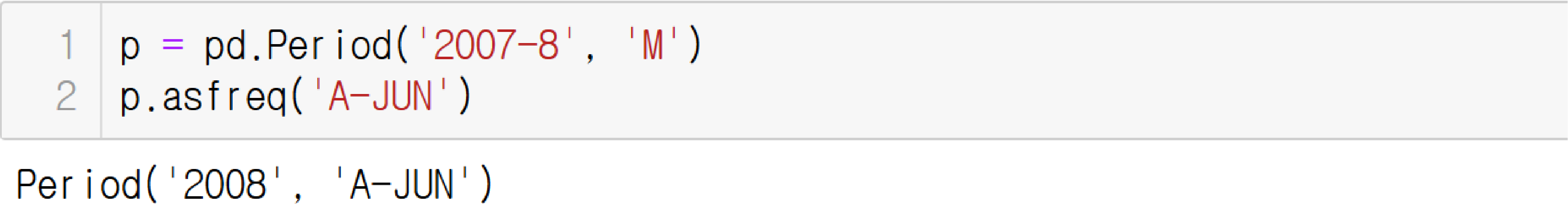
```
p.asfreq('M', 'end')
```

```
Period('2007-06', 'M')
```

Period Frequency Conversion



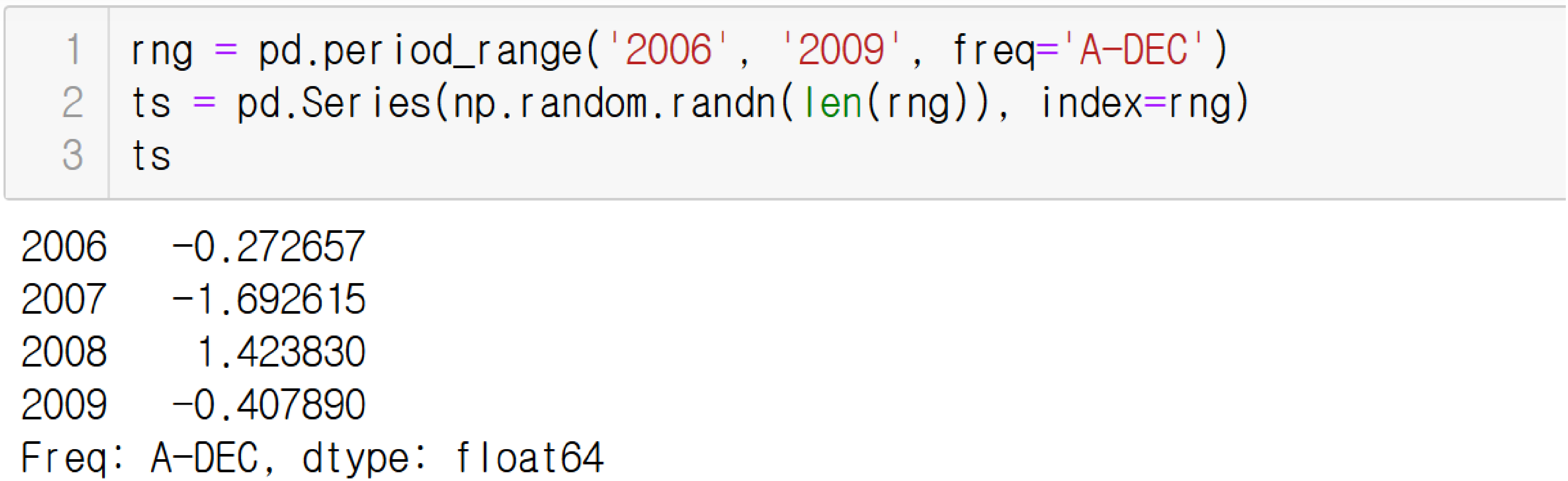
Period Frequency Conversion



```
p = pd.Period('2007-8', 'M')
p.asfreq('A-JUN')
```

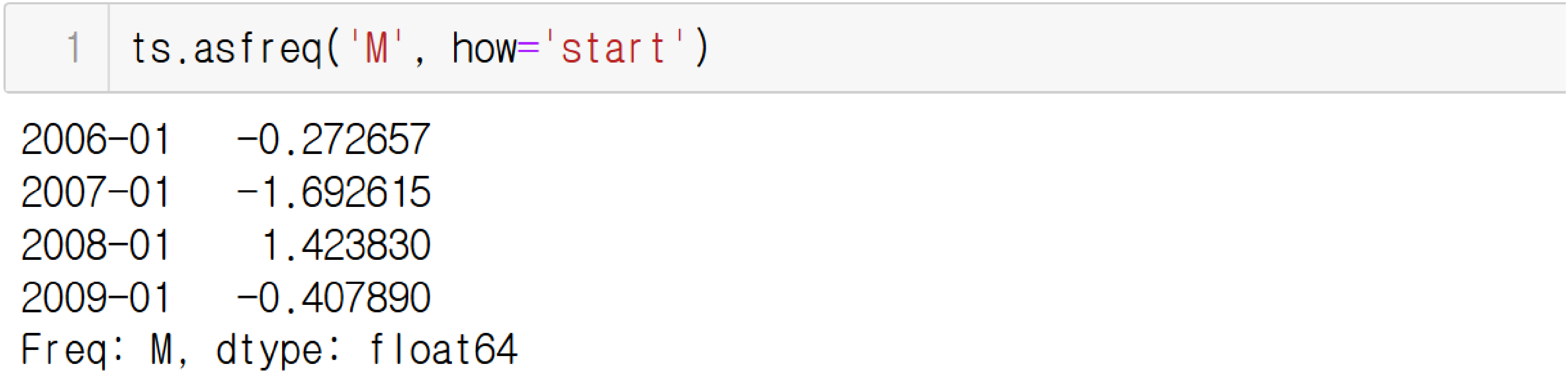
```
Period('2008', 'A-JUN')
```

Period Frequency Conversion



```python
rng = pd.period_range('2006', '2009', freq='A-DEC')
ts = pd.Series(np.random.randn(len(rng)), index=rng)
ts
```

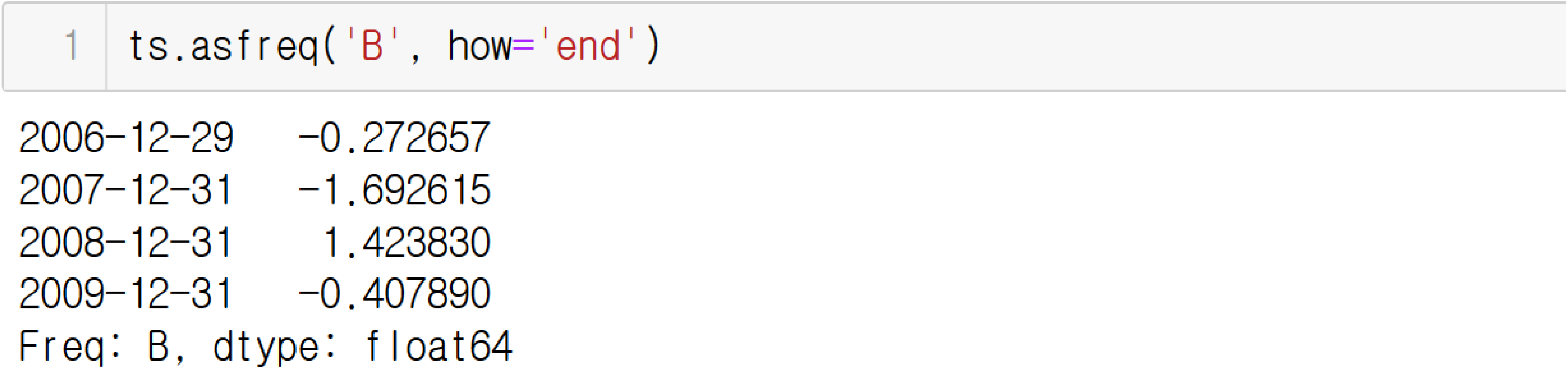
```
2006   -0.272657
2007   -1.692615
2008    1.423830
2009   -0.407890
Freq: A-DEC, dtype: float64
```



```python
ts.asfreq('M', how='start')
```

```
2006-01   -0.272657
2007-01   -1.692615
2008-01    1.423830
2009-01   -0.407890
Freq: M, dtype: float64
```

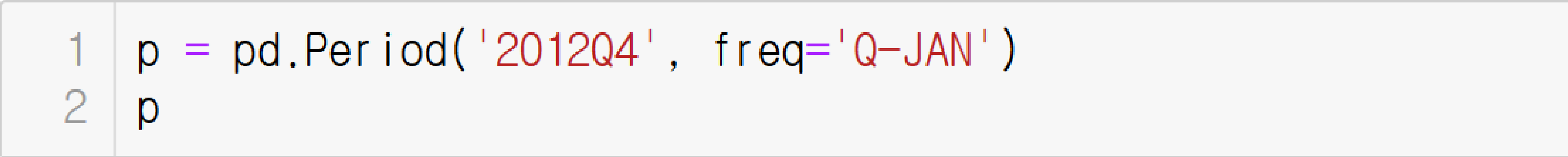
Period Frequency Conversion



```python
ts.asfreq('B', how='end')
```

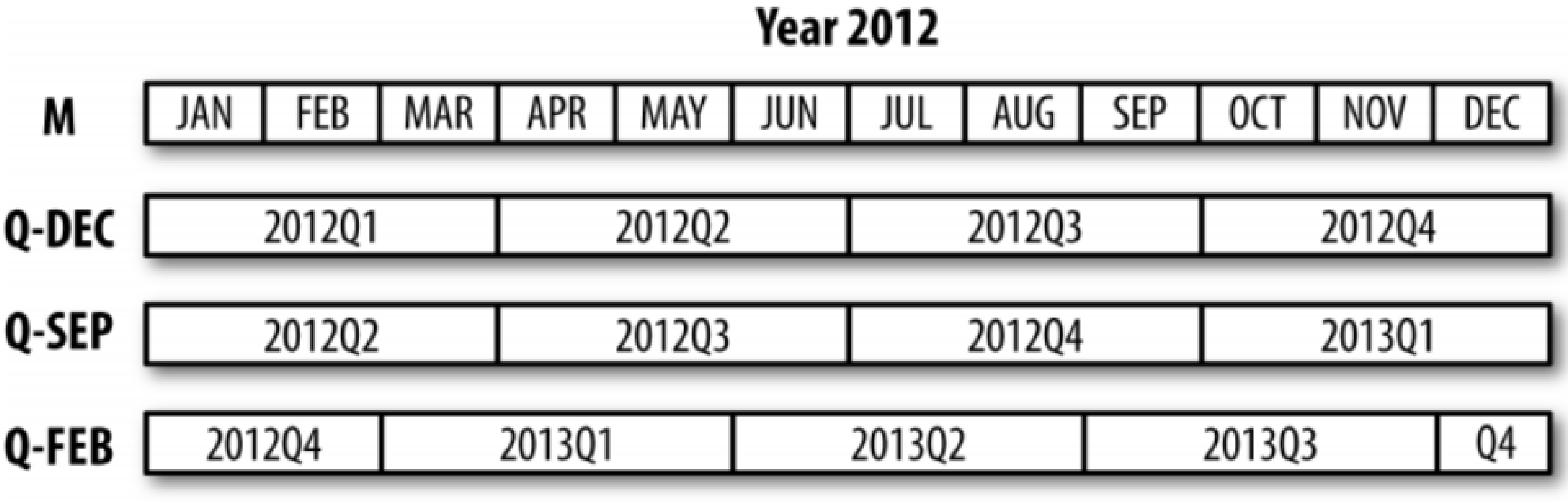
```
2006-12-29   -0.272657
2007-12-31   -1.692615
2008-12-31    1.423830
2009-12-31   -0.407890
Freq: B, dtype: float64
```

Quarterly Period Frequencies



```
p = pd.Period('2012Q4', freq='Q-JAN')
p
```

```
Period('2012Q4', 'Q-JAN')
```

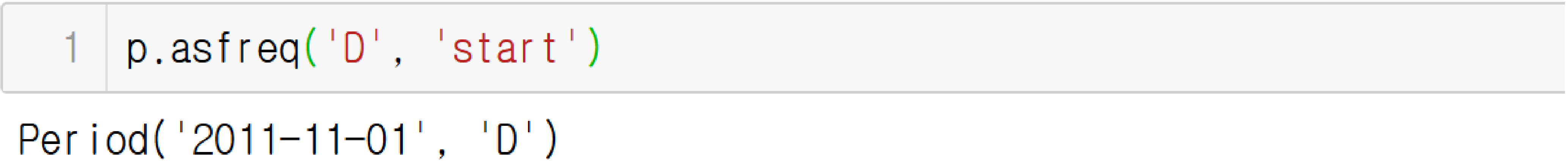


Year 2012

M	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Q-DEC	2012Q1			2012Q2			2012Q3			2012Q4		
Q-SEP	2012Q2			2012Q3			2012Q4			2013Q1		
Q-FEB	2012Q4		2013Q1			2013Q2			2013Q3			Q4

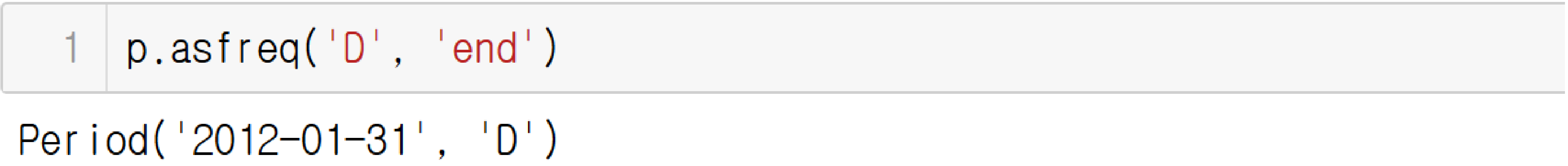
Different quarterly frequency conventions

Quarterly Period Frequencies



```python
p.asfreq('D', 'start')
```

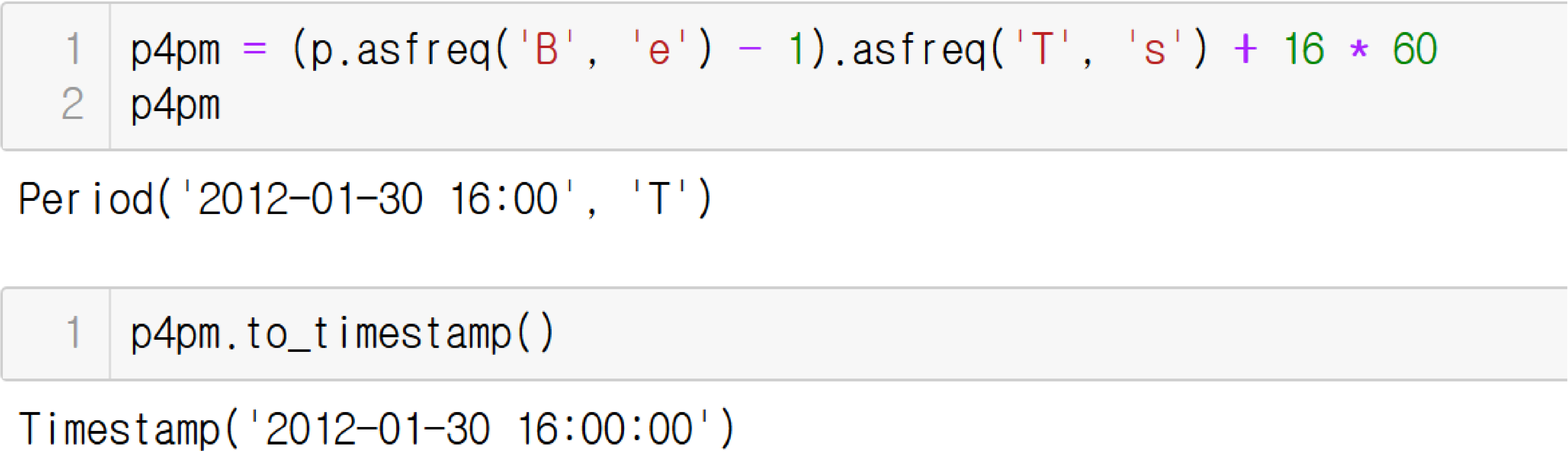
```
Period('2011-11-01', 'D')
```



```python
p.asfreq('D', 'end')
```

```
Period('2012-01-31', 'D')
```

Quarterly Period Frequencies



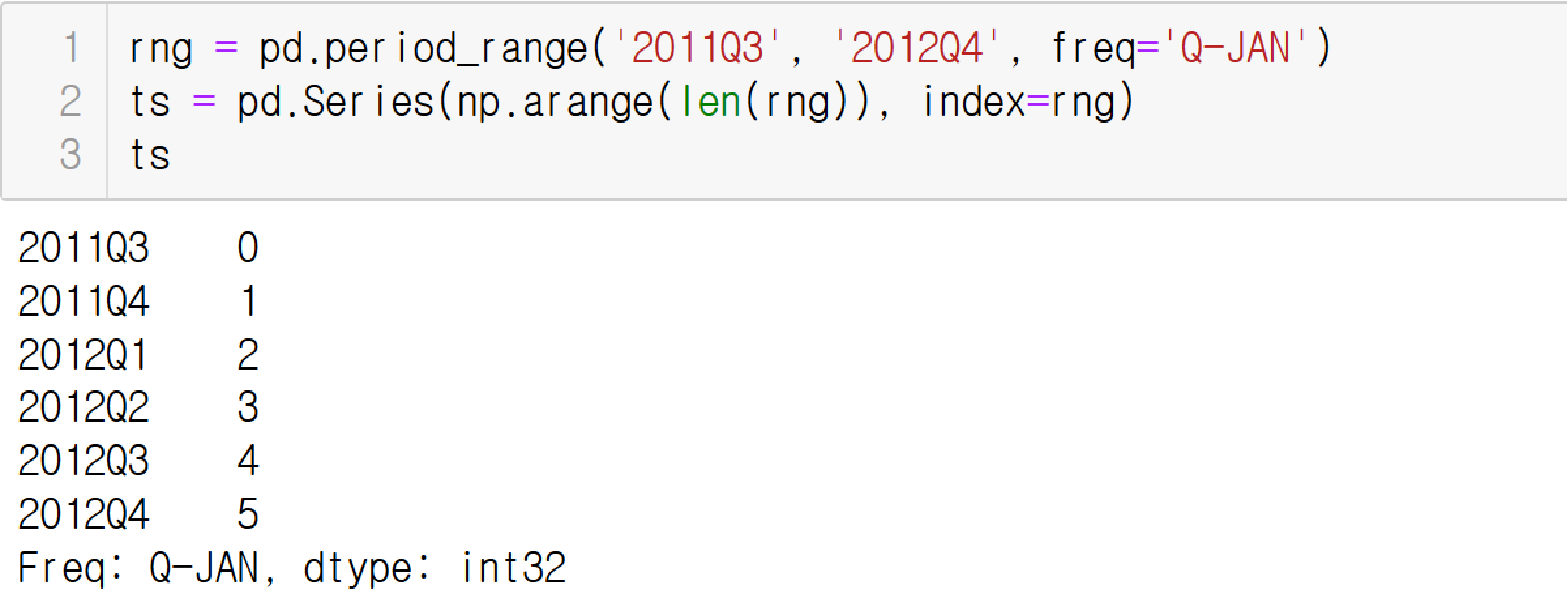
```python
p4pm = (p.asfreq('B', 'e') - 1).asfreq('T', 's') + 16 * 60
p4pm
```

```
Period('2012-01-30 16:00', 'T')
```

```python
p4pm.to_timestamp()
```

```
Timestamp('2012-01-30 16:00:00')
```

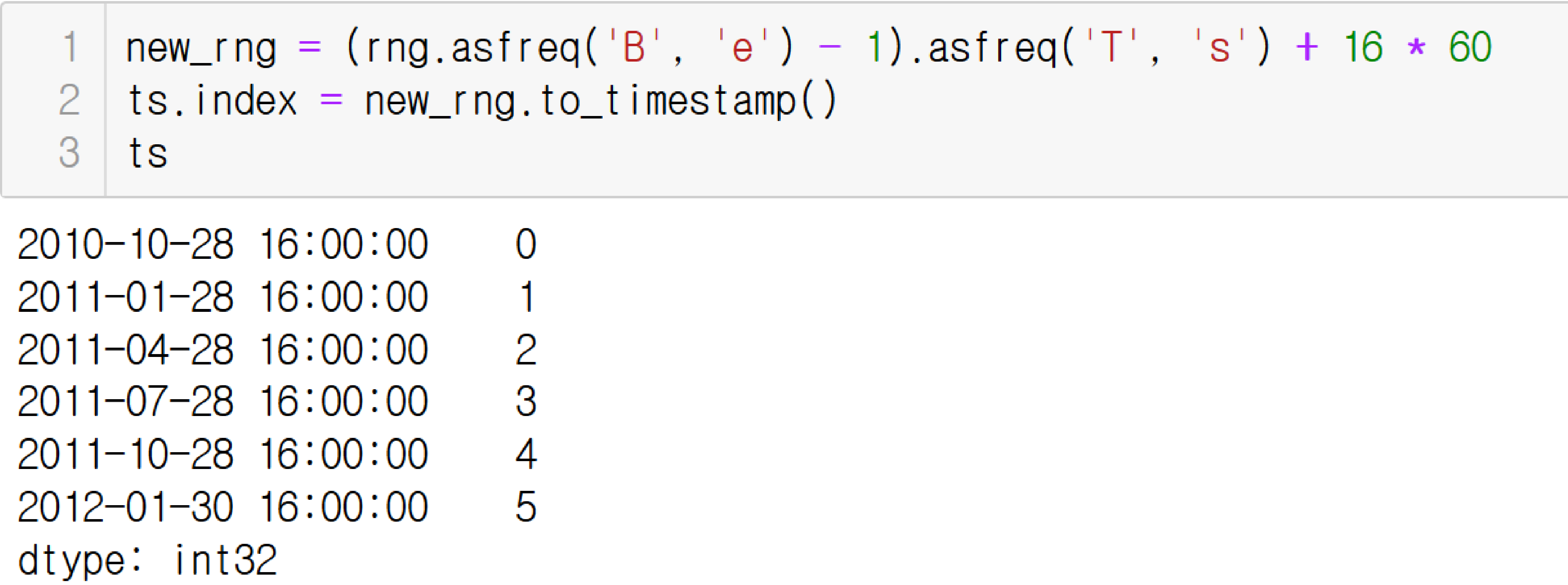
Quarterly Period Frequencies



```python
rng = pd.period_range('2011Q3', '2012Q4', freq='Q-JAN')
ts = pd.Series(np.arange(len(rng)), index=rng)
ts
```

```
2011Q3    0
2011Q4    1
2012Q1    2
2012Q2    3
2012Q3    4
2012Q4    5
Freq: Q-JAN, dtype: int32
```

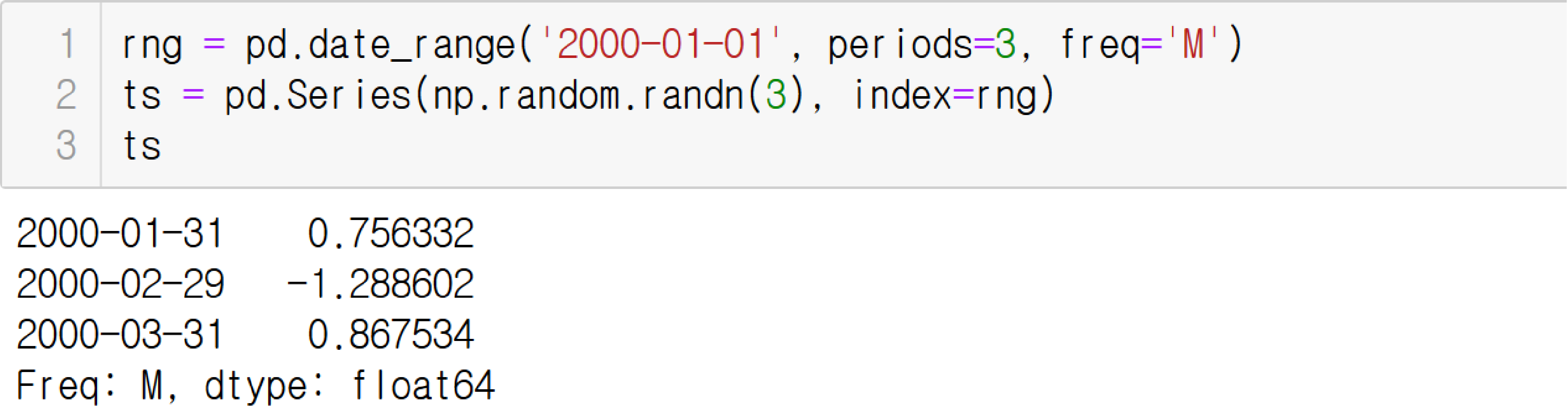
Quarterly Period Frequencies



```
new_rng = (rng.asfreq('B', 'e') - 1).asfreq('T', 's') + 16 * 60
ts.index = new_rng.to_timestamp()
ts
```

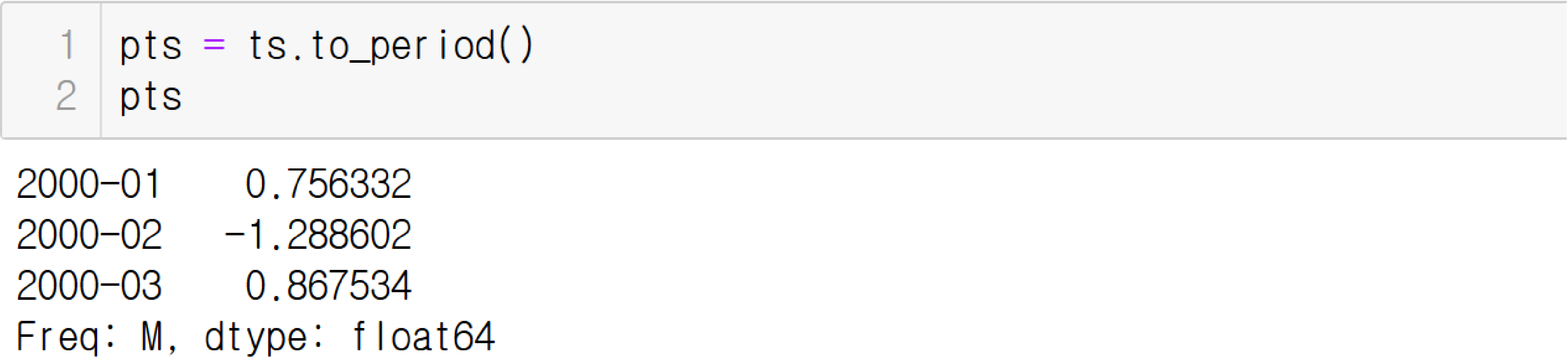
```
2010-10-28 16:00:00    0
2011-01-28 16:00:00    1
2011-04-28 16:00:00    2
2011-07-28 16:00:00    3
2011-10-28 16:00:00    4
2012-01-30 16:00:00    5
dtype: int32
```

Converting Timestamps to Periods (and Back)



```python
rng = pd.date_range('2000-01-01', periods=3, freq='M')
ts = pd.Series(np.random.randn(3), index=rng)
ts
```

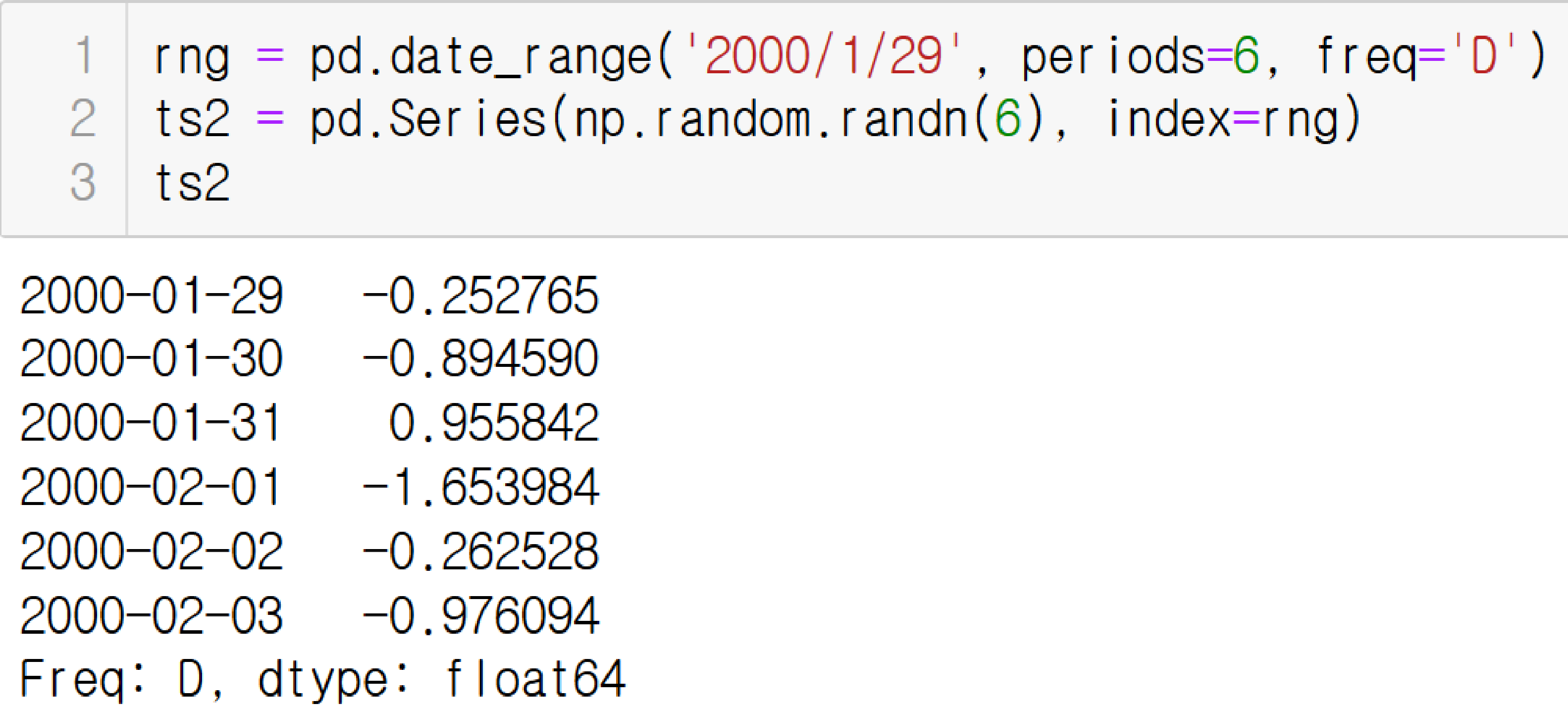
```
2000-01-31    0.756332
2000-02-29   -1.288602
2000-03-31    0.867534
Freq: M, dtype: float64
```



```python
pts = ts.to_period()
pts
```

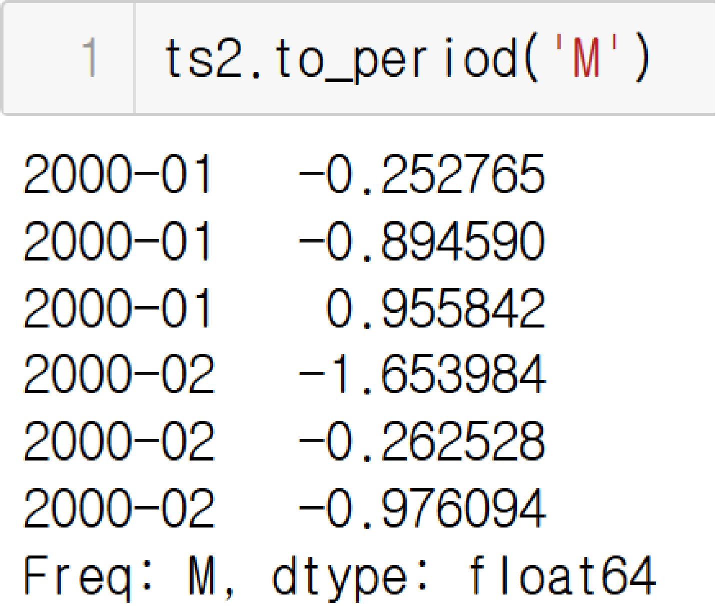
```
2000-01    0.756332
2000-02   -1.288602
2000-03    0.867534
Freq: M, dtype: float64
```

Converting Timestamps to Periods (and Back)



```python
rng = pd.date_range('2000/1/29', periods=6, freq='D')
ts2 = pd.Series(np.random.randn(6), index=rng)
ts2
```

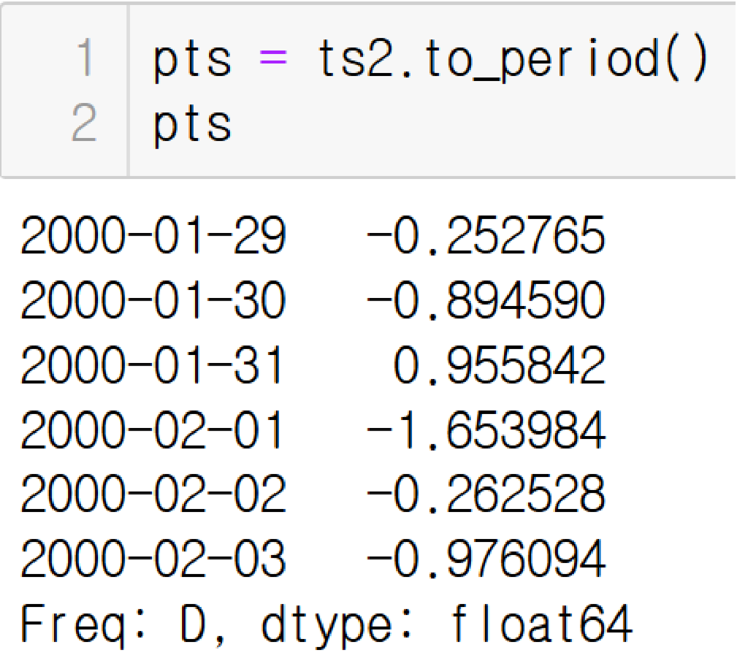
```
2000-01-29   -0.252765
2000-01-30   -0.894590
2000-01-31    0.955842
2000-02-01   -1.653984
2000-02-02   -0.262528
2000-02-03   -0.976094
Freq: D, dtype: float64
```



```python
ts2.to_period('M')
```

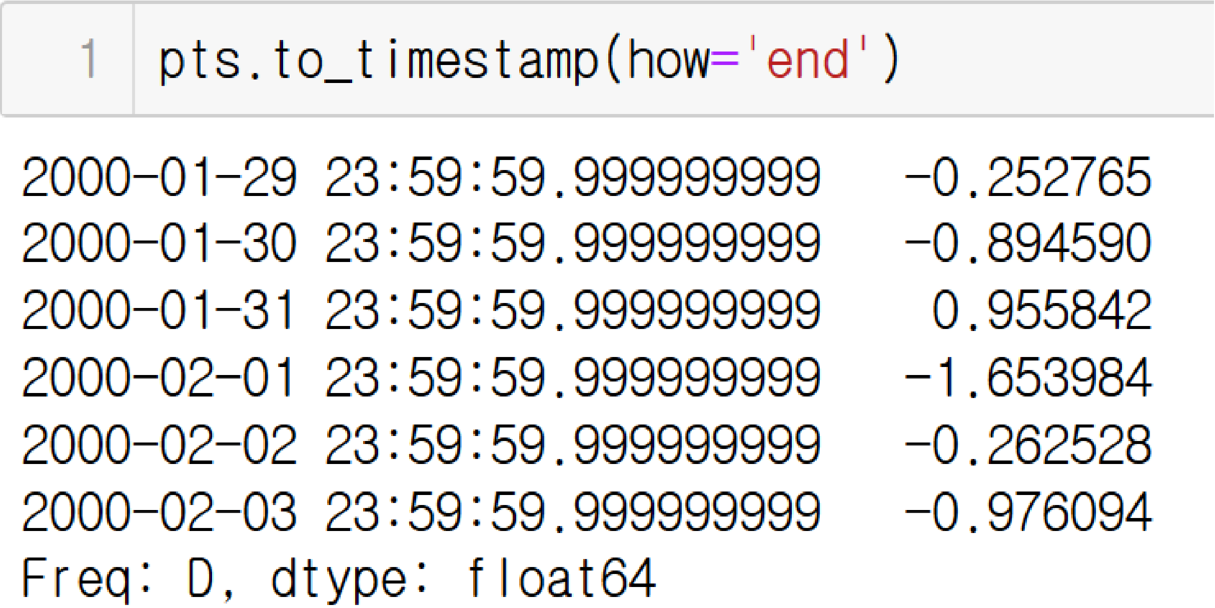
```
2000-01   -0.252765
2000-01   -0.894590
2000-01    0.955842
2000-02   -1.653984
2000-02   -0.262528
2000-02   -0.976094
Freq: M, dtype: float64
```

Converting Timestamps to Periods (and Back)



```python
pts = ts2.to_period()
pts
```

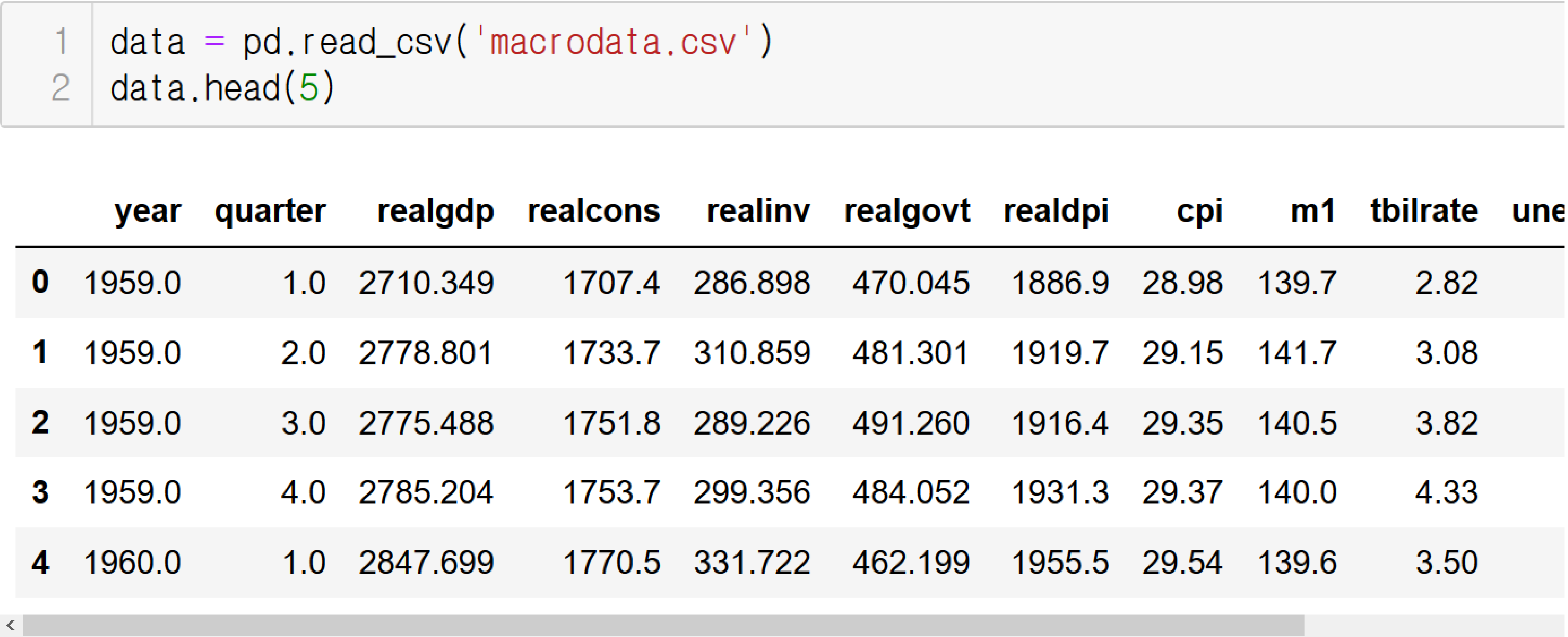
```
2000-01-29   -0.252765
2000-01-30   -0.894590
2000-01-31    0.955842
2000-02-01   -1.653984
2000-02-02   -0.262528
2000-02-03   -0.976094
Freq: D, dtype: float64
```



```python
pts.to_timestamp(how='end')
```

```
2000-01-29 23:59:59.999999999   -0.252765
2000-01-30 23:59:59.999999999   -0.894590
2000-01-31 23:59:59.999999999    0.955842
2000-02-01 23:59:59.999999999   -1.653984
2000-02-02 23:59:59.999999999   -0.262528
2000-02-03 23:59:59.999999999   -0.976094
Freq: D, dtype: float64
```

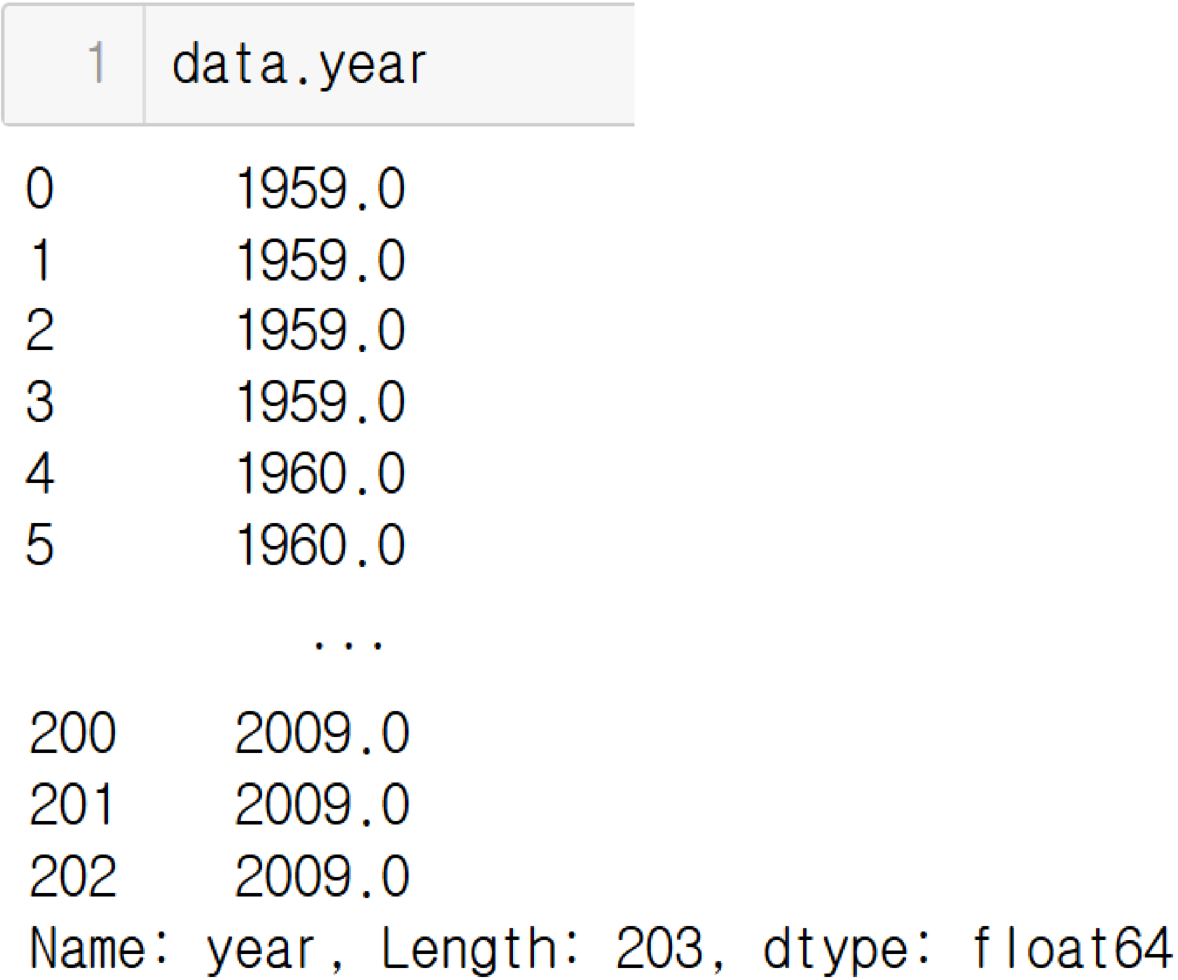
Creating a PeriodIndex from Arrays



```python
data = pd.read_csv('macrodata.csv')
data.head(5)
```

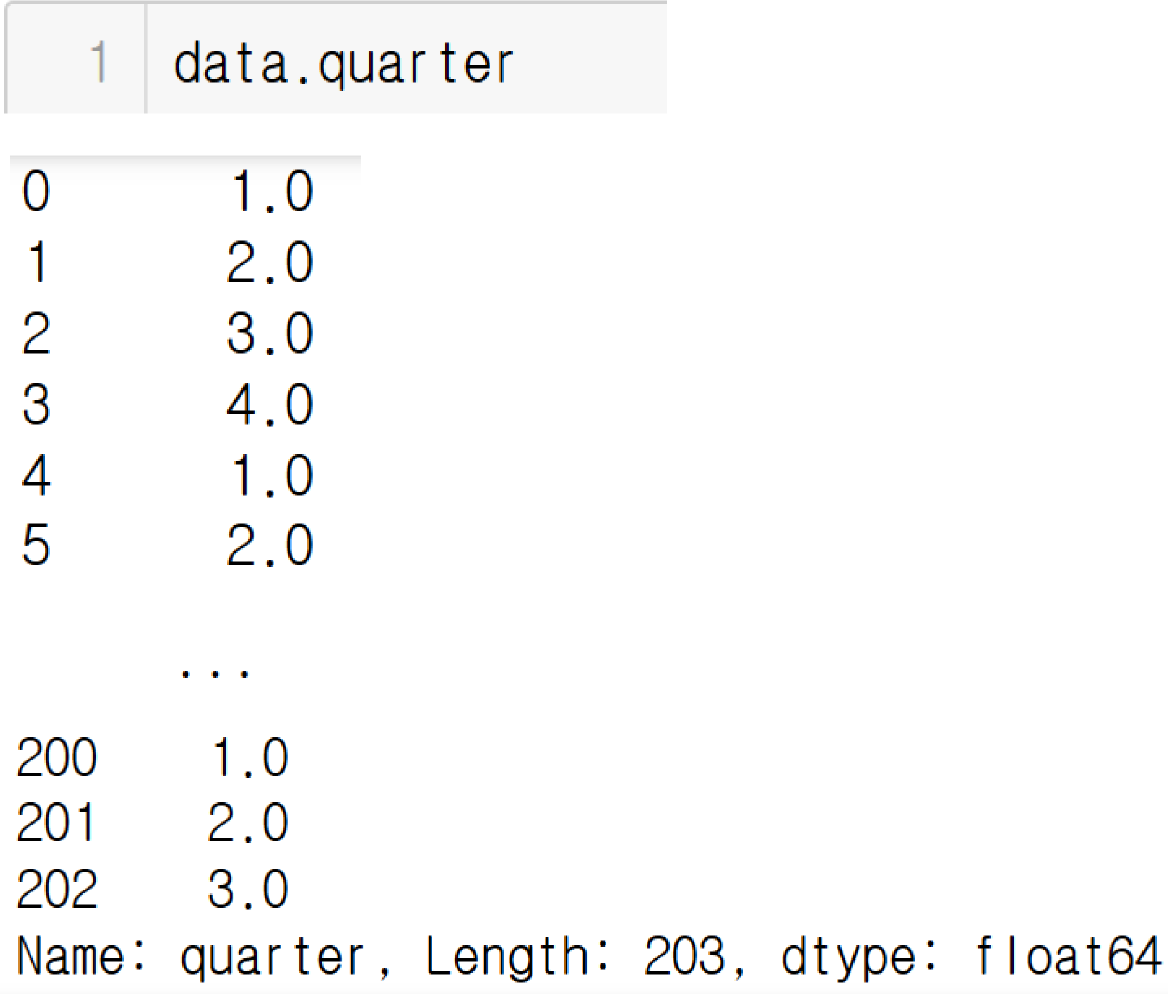
	year	quarter	realgdp	realcons	realinv	realgovt	realdpi	cpi	m1	tbilrate	une
0	1959.0	1.0	2710.349	1707.4	286.898	470.045	1886.9	28.98	139.7	2.82	
1	1959.0	2.0	2778.801	1733.7	310.859	481.301	1919.7	29.15	141.7	3.08	
2	1959.0	3.0	2775.488	1751.8	289.226	491.260	1916.4	29.35	140.5	3.82	
3	1959.0	4.0	2785.204	1753.7	299.356	484.052	1931.3	29.37	140.0	4.33	
4	1960.0	1.0	2847.699	1770.5	331.722	462.199	1955.5	29.54	139.6	3.50	

Creating a PeriodIndex from Arrays



```
data.year
```

```
0       1959.0
1       1959.0
2       1959.0
3       1959.0
4       1960.0
5       1960.0
           ...
200     2009.0
201     2009.0
202     2009.0
Name: year, Length: 203, dtype: float64
```



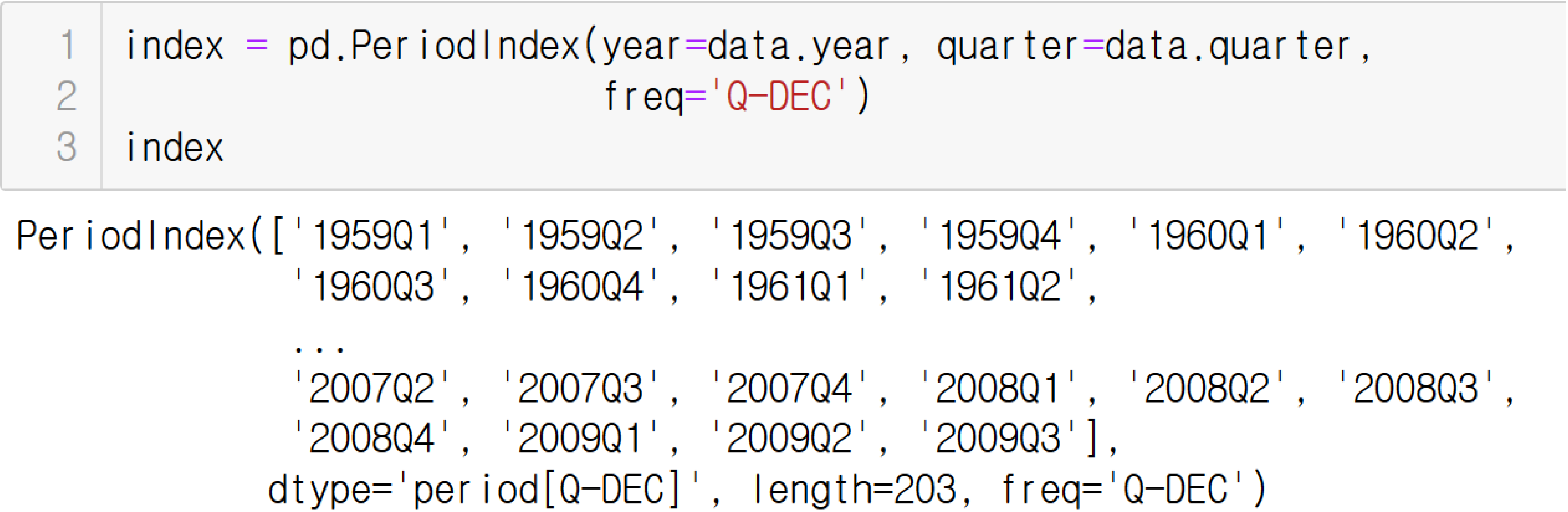
```
data.quarter
```

```
0          1.0
1          2.0
2          3.0
3          4.0
4          1.0
5          2.0

       ...

200     1.0
201     2.0
202     3.0
Name: quarter, Length: 203, dtype: float64
```

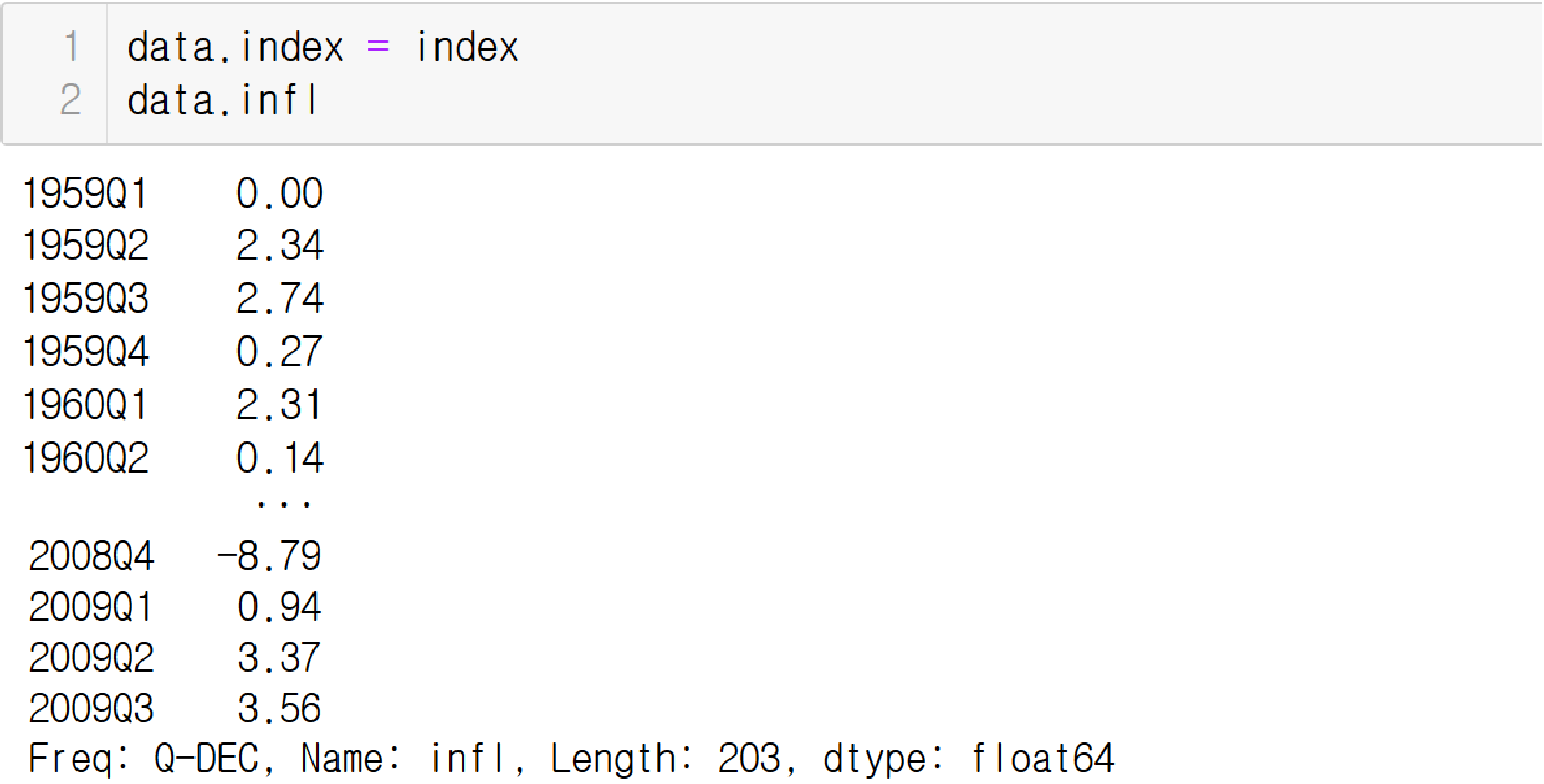
Creating a PeriodIndex from Arrays



```python
index = pd.PeriodIndex(year=data.year, quarter=data.quarter,
                       freq='Q-DEC')
index
```

```
PeriodIndex(['1959Q1', '1959Q2', '1959Q3', '1959Q4', '1960Q1', '1960Q2',
             '1960Q3', '1960Q4', '1961Q1', '1961Q2',
             ...
             '2007Q2', '2007Q3', '2007Q4', '2008Q1', '2008Q2', '2008Q3',
             '2008Q4', '2009Q1', '2009Q2', '2009Q3'],
            dtype='period[Q-DEC]', length=203, freq='Q-DEC')
```

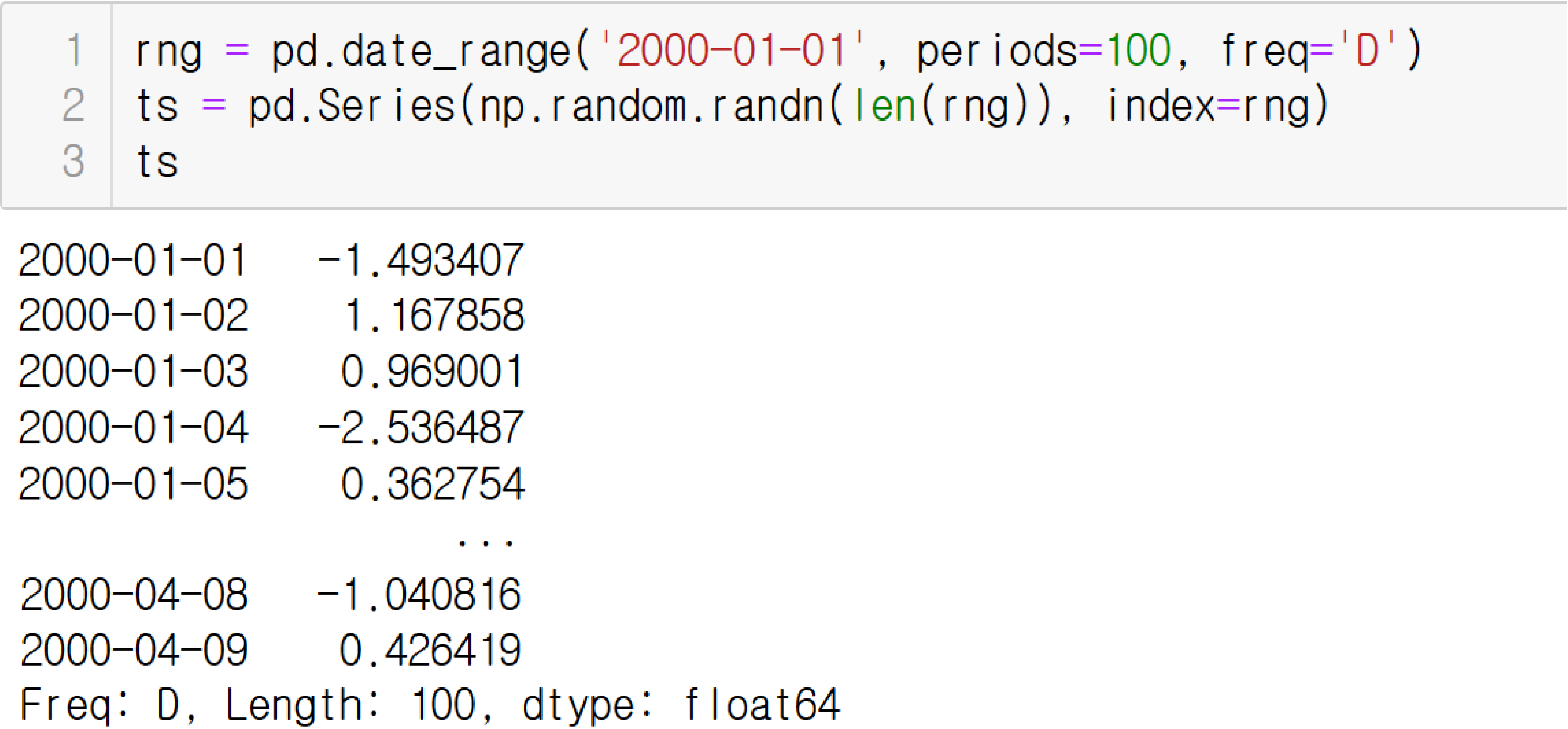
Creating a PeriodIndex from Arrays



```
data.index = index
data.infl
```

```
1959Q1     0.00
1959Q2     2.34
1959Q3     2.74
1959Q4     0.27
1960Q1     2.31
1960Q2     0.14
            ...
2008Q4    -8.79
2009Q1     0.94
2009Q2     3.37
2009Q3     3.56
Freq: Q-DEC, Name: infl, Length: 203, dtype: float64
```

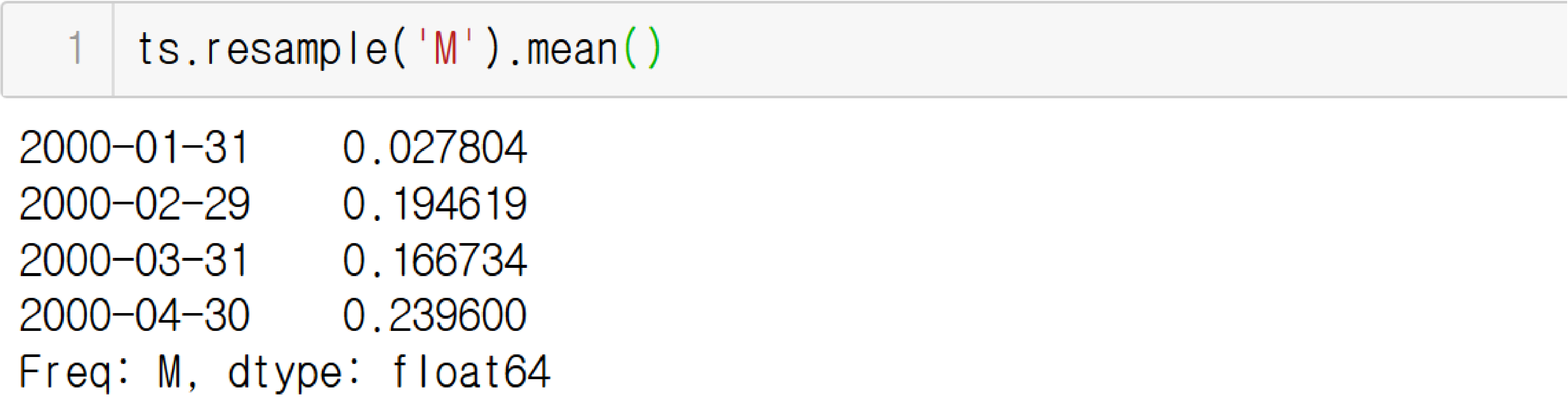
Resampling and Frequency Conversion



```python
rng = pd.date_range('2000-01-01', periods=100, freq='D')
ts = pd.Series(np.random.randn(len(rng)), index=rng)
ts
```

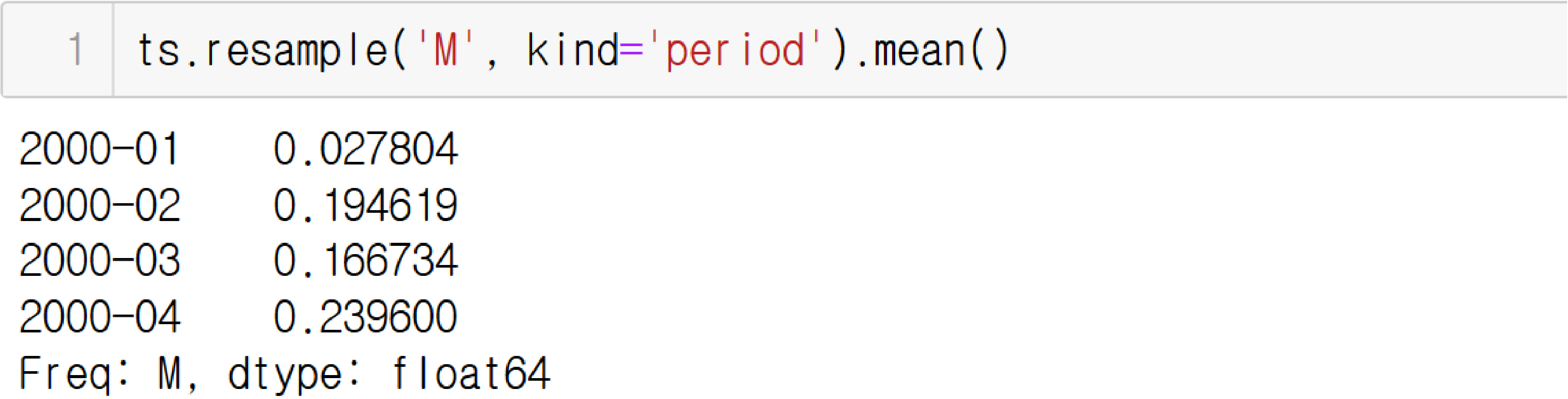
```
2000-01-01   -1.493407
2000-01-02    1.167858
2000-01-03    0.969001
2000-01-04   -2.536487
2000-01-05    0.362754
                ...
2000-04-08   -1.040816
2000-04-09    0.426419
Freq: D, Length: 100, dtype: float64
```

Resampling and Frequency Conversion



```
ts.resample('M').mean()
```

```
2000-01-31    0.027804
2000-02-29    0.194619
2000-03-31    0.166734
2000-04-30    0.239600
Freq: M, dtype: float64
```

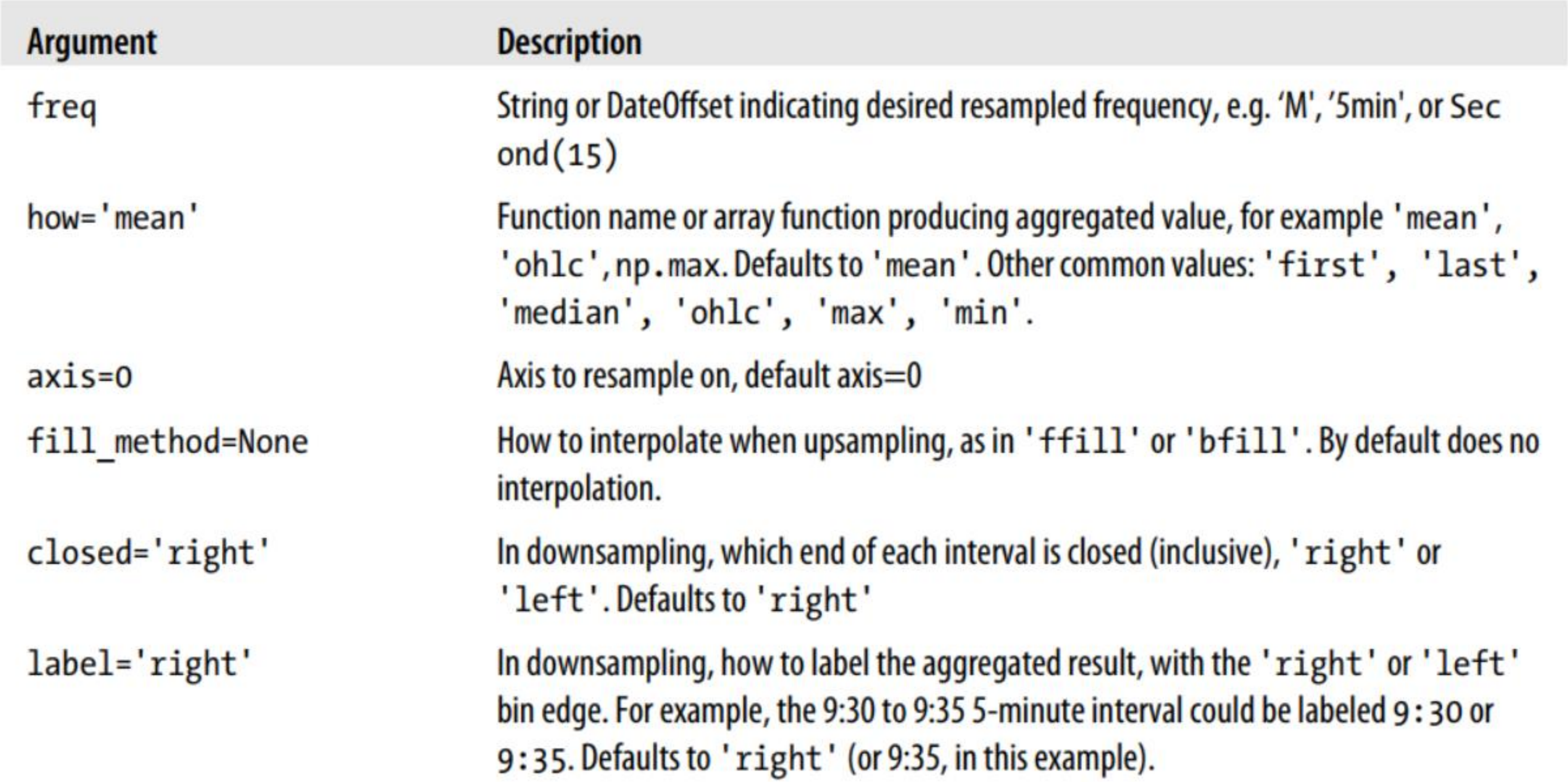


```
ts.resample('M', kind='period').mean()
```

```
2000-01    0.027804
2000-02    0.194619
2000-03    0.166734
2000-04    0.239600
Freq: M, dtype: float64
```

Resampling and Frequency Conversion

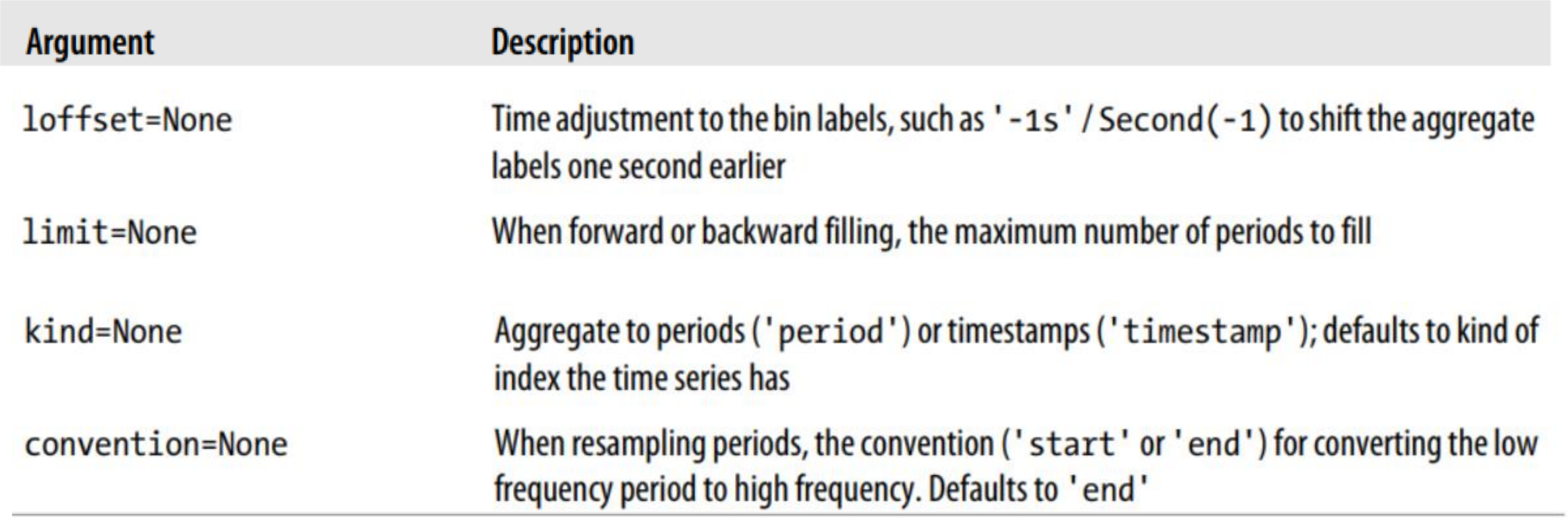
resample method arguments



Argument	Description
freq	String or DateOffset indicating desired resampled frequency, e.g. ‘M’, ’5min’, or Second(15)
how='mean'	Function name or array function producing aggregated value, for example 'mean', 'ohlc',np.max. Defaults to 'mean'. Other common values: 'first', 'last', 'median', 'ohlc', 'max', 'min'.
axis=0	Axis to resample on, default axis=0
fill_method=None	How to interpolate when upsampling, as in 'ffill' or 'bfill'. By default does no interpolation.
closed='right'	In downsampling, which end of each interval is closed (inclusive), 'right' or 'left'. Defaults to 'right'
label='right'	In downsampling, how to label the aggregated result, with the 'right' or 'left' bin edge. For example, the 9:30 to 9:35 5-minute interval could be labeled 9:30 or 9:35. Defaults to 'right' (or 9:35, in this example).

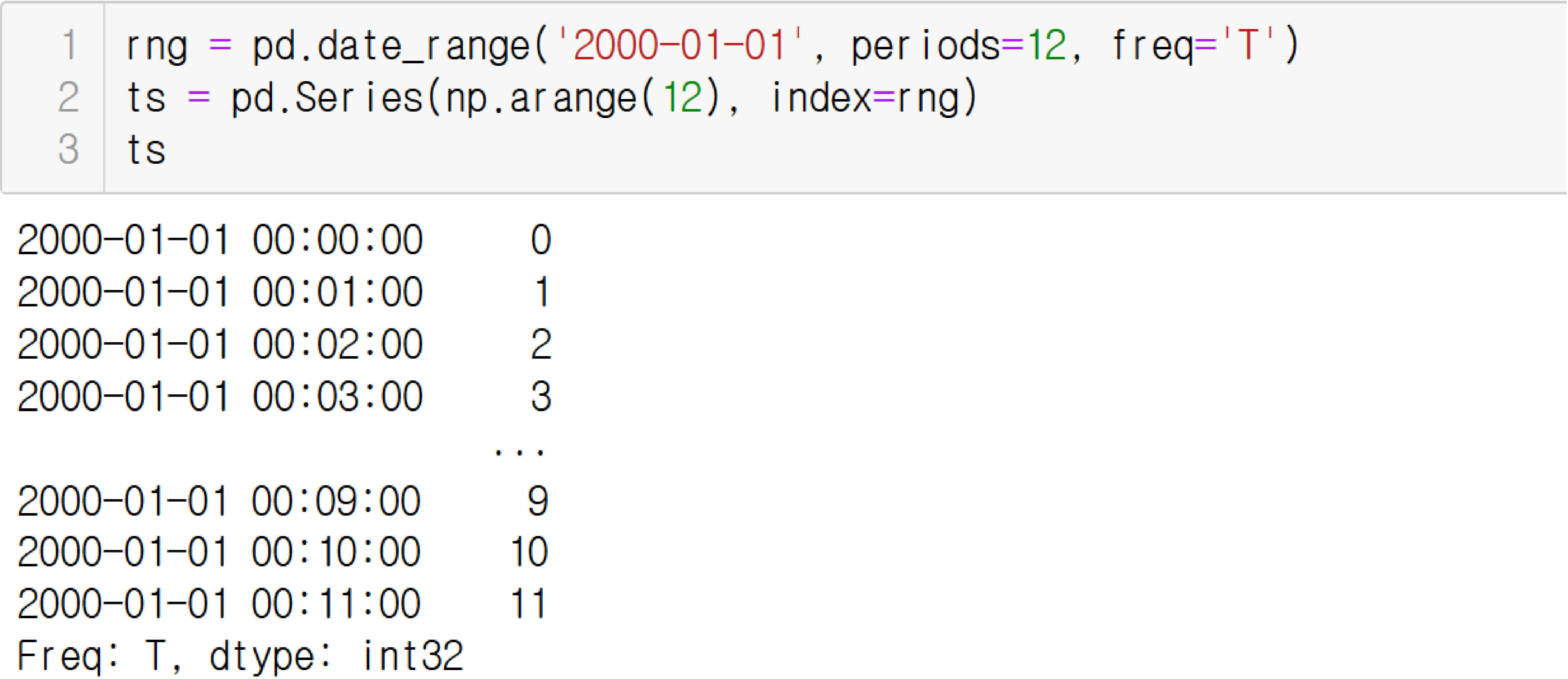
Resampling and Frequency Conversion

resample method arguments



Argument	Description
`loffset=None`	Time adjustment to the bin labels, such as `'-1s'` / `Second(-1)` to shift the aggregate labels one second earlier
`limit=None`	When forward or backward filling, the maximum number of periods to fill
`kind=None`	Aggregate to periods (`'period'`) or timestamps (`'timestamp'`); defaults to kind of index the time series has
`convention=None`	When resampling periods, the convention (`'start'` or `'end'`) for converting the low frequency period to high frequency. Defaults to `'end'`

Downsampling

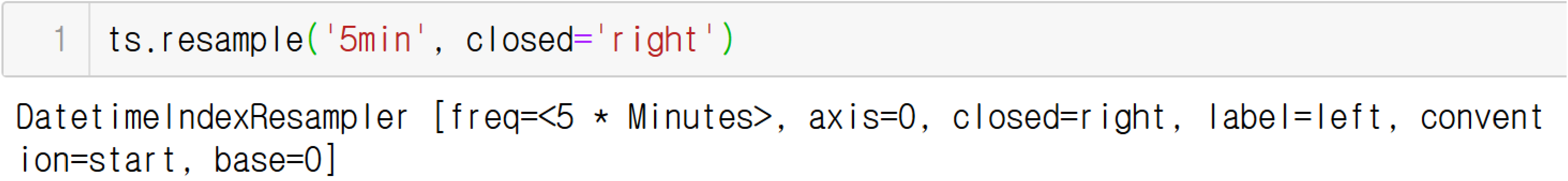


```
rng = pd.date_range('2000-01-01', periods=12, freq='T')
ts = pd.Series(np.arange(12), index=rng)
ts
```

```
2000-01-01 00:00:00     0
2000-01-01 00:01:00     1
2000-01-01 00:02:00     2
2000-01-01 00:03:00     3
                      ...
2000-01-01 00:09:00     9
2000-01-01 00:10:00    10
2000-01-01 00:11:00    11
Freq: T, dtype: int32
```

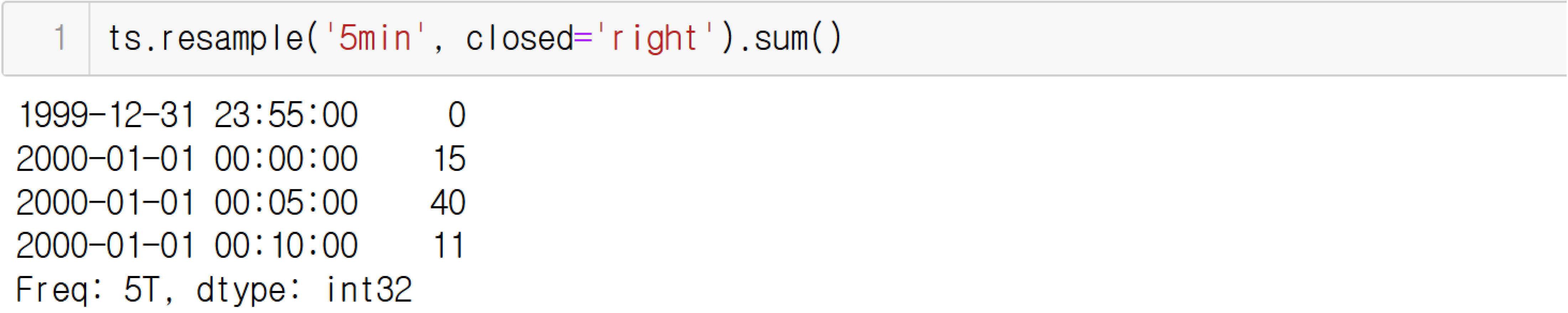
Downsampling

- Which side of each interval is *closed*
- How to label each aggregated bin, either with the start of the interval or the end



```
ts.resample('5min', closed='right')
```

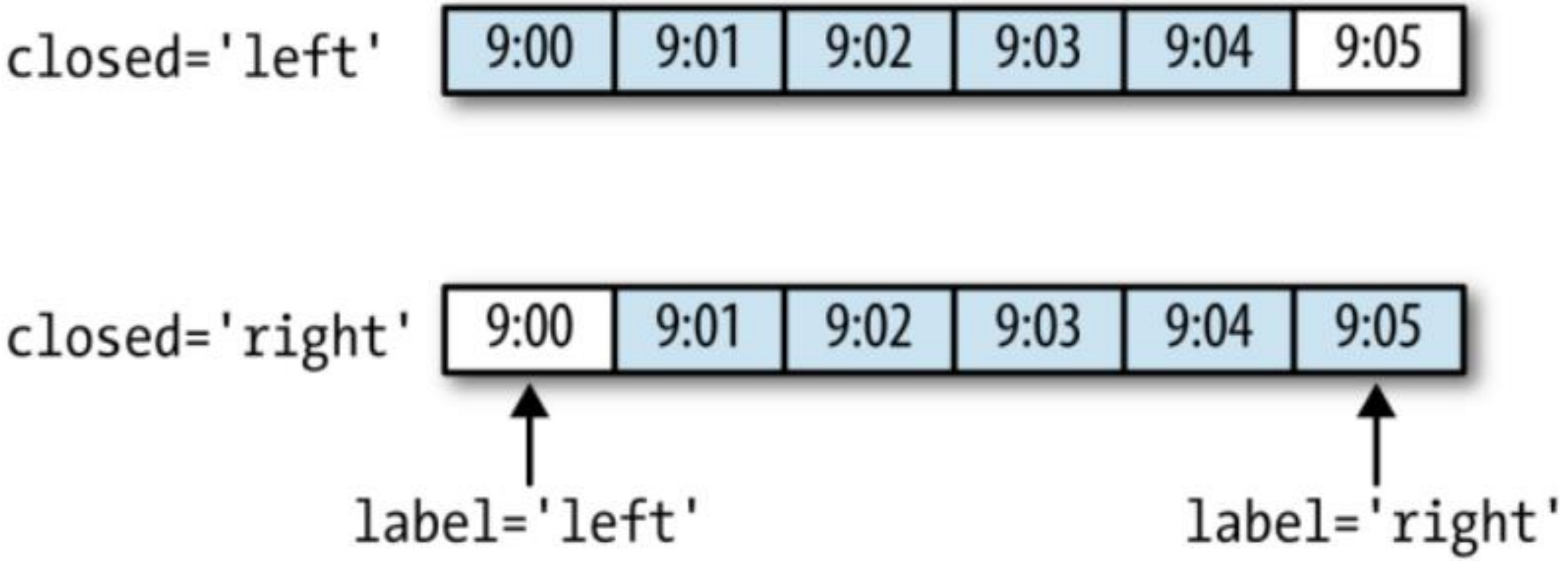
```
DatetimeIndexResampler [freq=<5 * Minutes>, axis=0, closed=right, label=left, convent
ion=start, base=0]
```



```
ts.resample('5min', closed='right').sum()
```

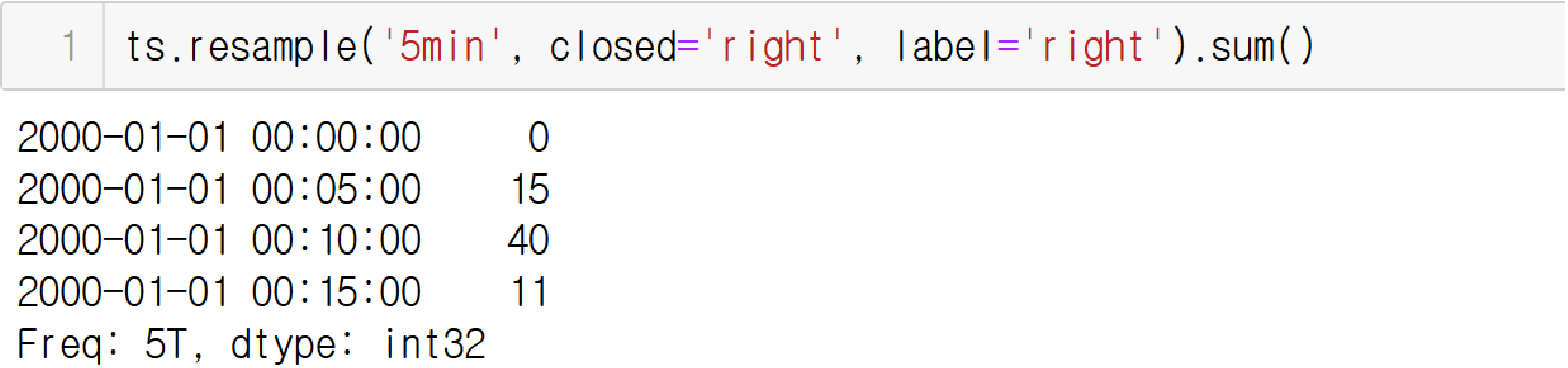
```
1999-12-31 23:55:00     0
2000-01-01 00:00:00    15
2000-01-01 00:05:00    40
2000-01-01 00:10:00    11
Freq: 5T, dtype: int32
```

Downsampling



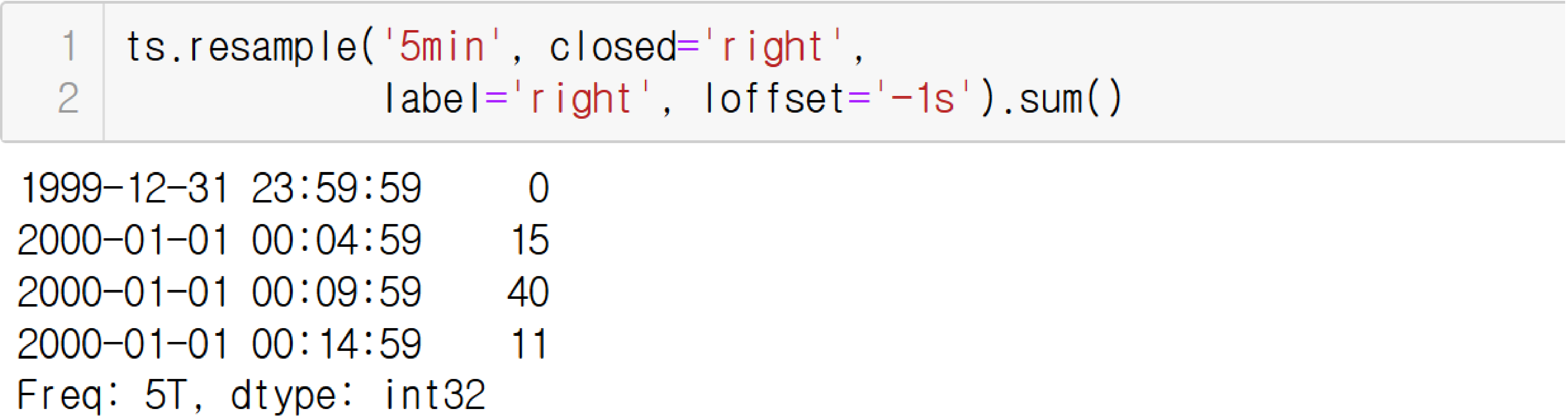
minute resampling of closed, label conventions

Downsampling



```
ts.resample('5min', closed='right', label='right').sum()
```

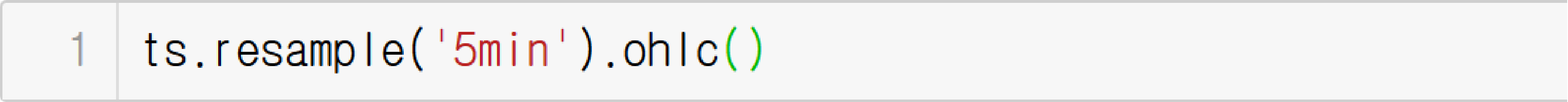
```
2000-01-01 00:00:00     0
2000-01-01 00:05:00    15
2000-01-01 00:10:00    40
2000-01-01 00:15:00    11
Freq: 5T, dtype: int32
```



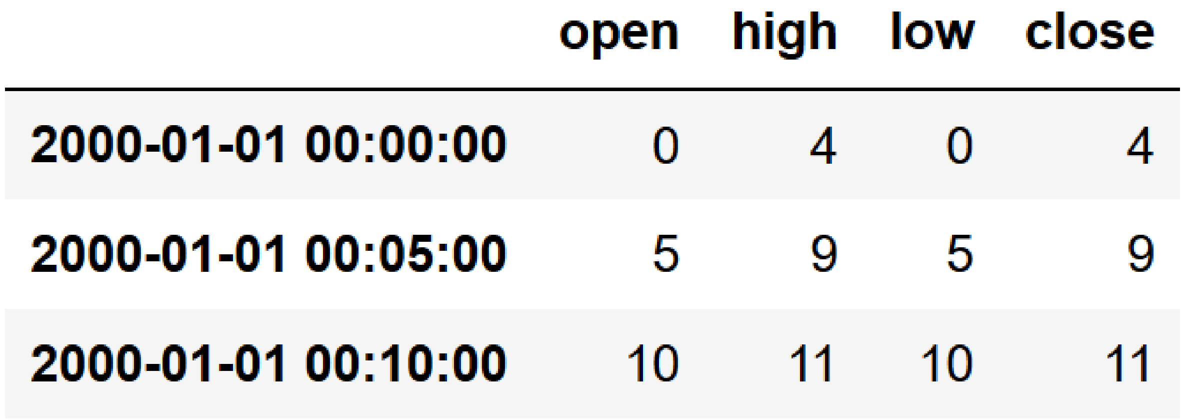
```
ts.resample('5min', closed='right',
            label='right', loffset='-1s').sum()
```

```
1999-12-31 23:59:59     0
2000-01-01 00:04:59    15
2000-01-01 00:09:59    40
2000-01-01 00:14:59    11
Freq: 5T, dtype: int32
```

Open-High-Low-Close (OHLC) resampling

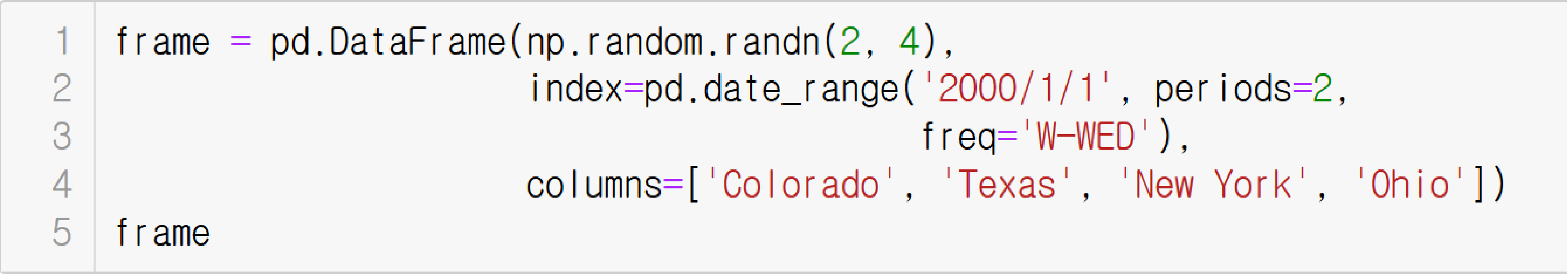


```python
ts.resample('5min').ohlc()
```

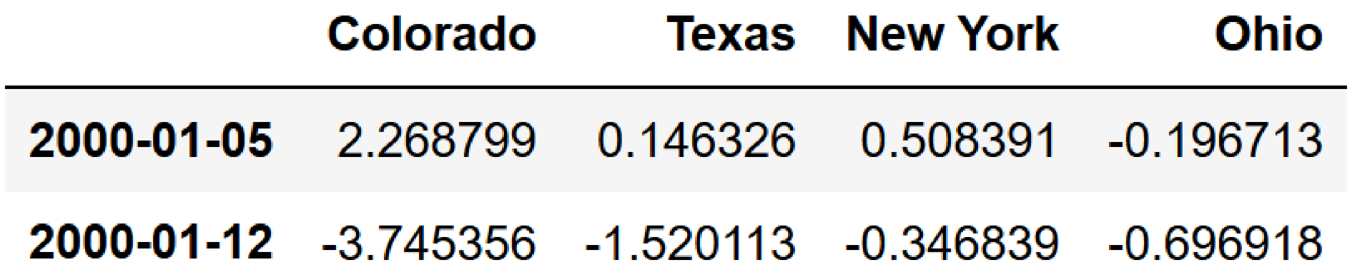


	open	high	low	close
2000-01-01 00:00:00	0	4	0	4
2000-01-01 00:05:00	5	9	5	9
2000-01-01 00:10:00	10	11	10	11

Upsampling and Interpolation

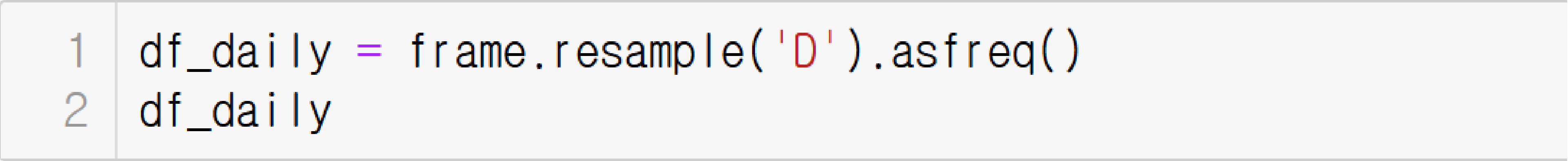


```
frame = pd.DataFrame(np.random.randn(2, 4),
                     index=pd.date_range('2000/1/1', periods=2,
                                         freq='W-WED'),
                     columns=['Colorado', 'Texas', 'New York', 'Ohio'])
frame
```

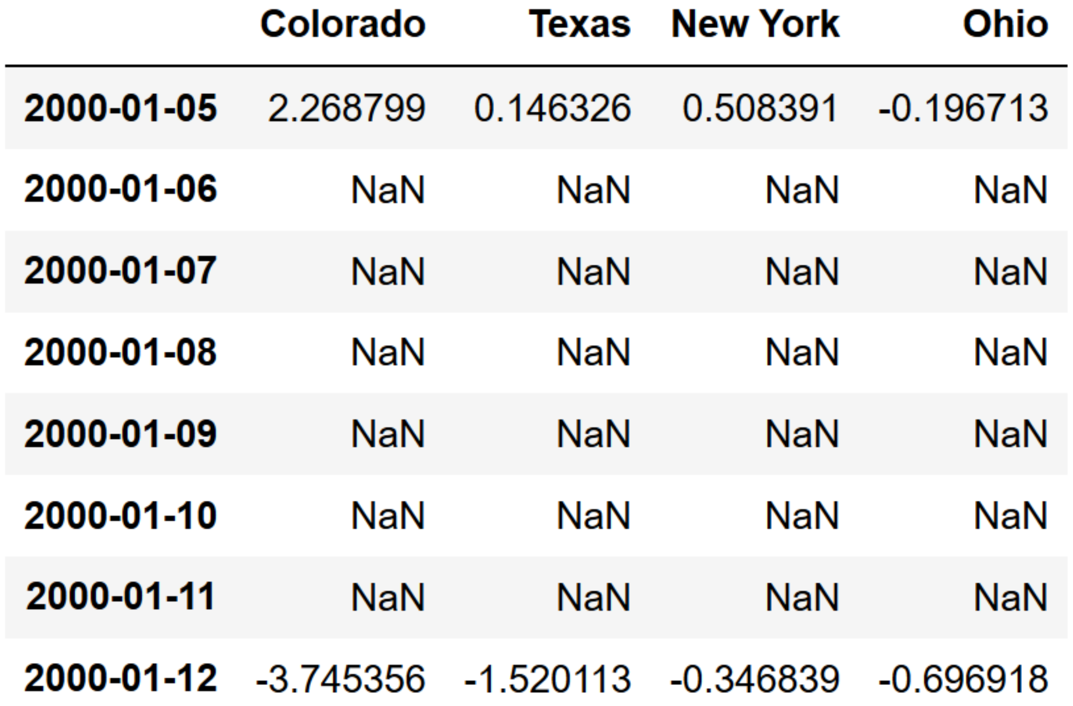


	Colorado	Texas	New York	Ohio
2000-01-05	2.268799	0.146326	0.508391	-0.196713
2000-01-12	-3.745356	-1.520113	-0.346839	-0.696918

Upsampling and Interpolation

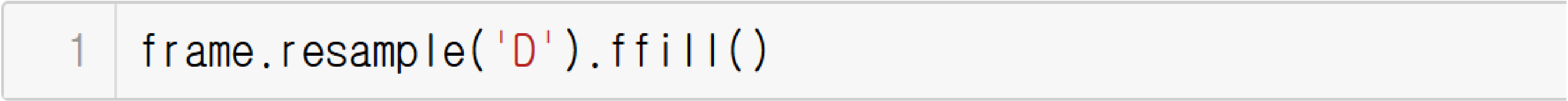


```python
df_daily = frame.resample('D').asfreq()
df_daily
```

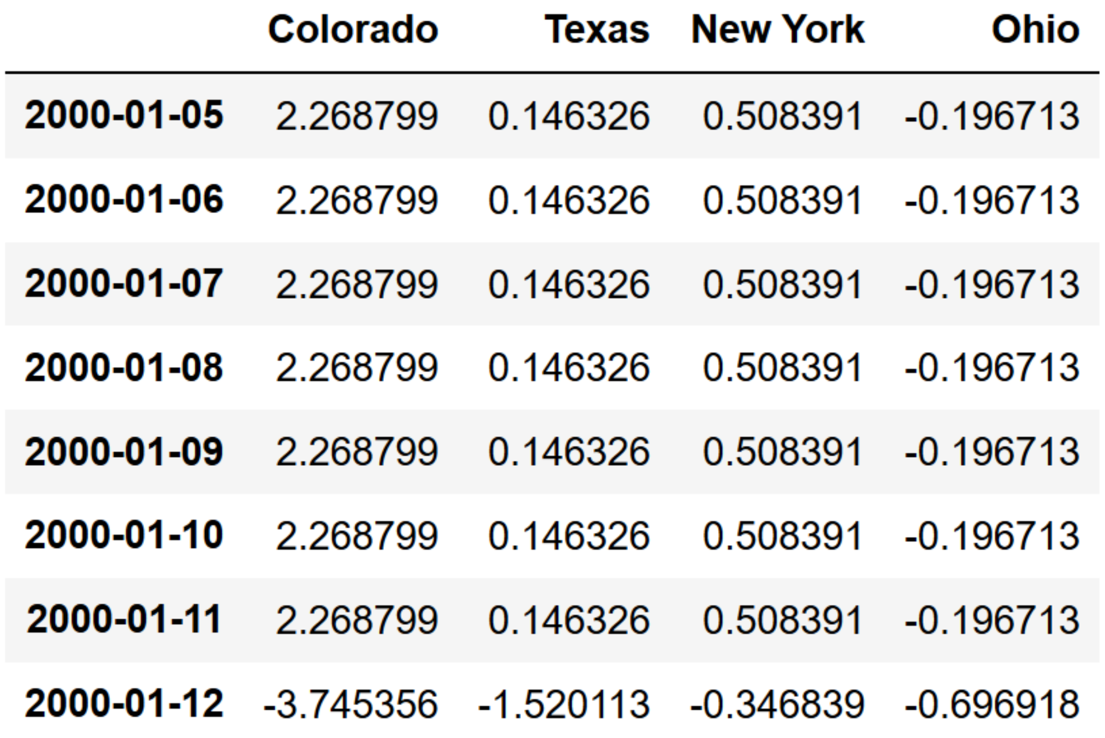


	Colorado	Texas	New York	Ohio
2000-01-05	2.268799	0.146326	0.508391	-0.196713
2000-01-06	NaN	NaN	NaN	NaN
2000-01-07	NaN	NaN	NaN	NaN
2000-01-08	NaN	NaN	NaN	NaN
2000-01-09	NaN	NaN	NaN	NaN
2000-01-10	NaN	NaN	NaN	NaN
2000-01-11	NaN	NaN	NaN	NaN
2000-01-12	-3.745356	-1.520113	-0.346839	-0.696918

Upsampling and Interpolation

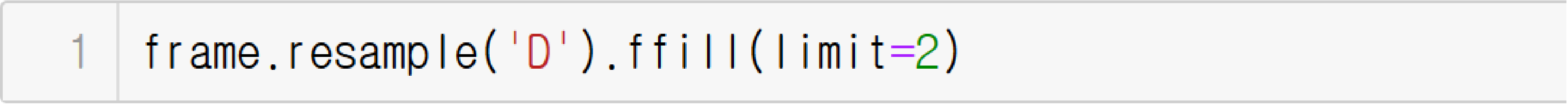


```
frame.resample('D').ffill()
```

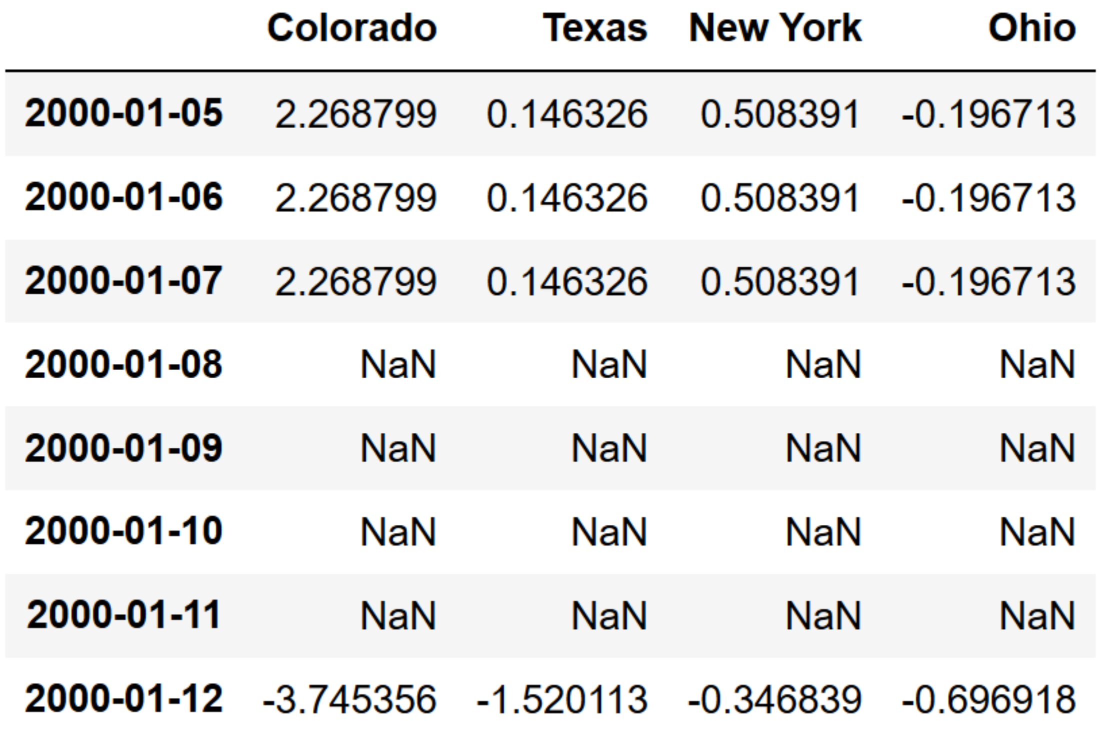


	Colorado	Texas	New York	Ohio
2000-01-05	2.268799	0.146326	0.508391	-0.196713
2000-01-06	2.268799	0.146326	0.508391	-0.196713
2000-01-07	2.268799	0.146326	0.508391	-0.196713
2000-01-08	2.268799	0.146326	0.508391	-0.196713
2000-01-09	2.268799	0.146326	0.508391	-0.196713
2000-01-10	2.268799	0.146326	0.508391	-0.196713
2000-01-11	2.268799	0.146326	0.508391	-0.196713
2000-01-12	-3.745356	-1.520113	-0.346839	-0.696918

Upsampling and Interpolation

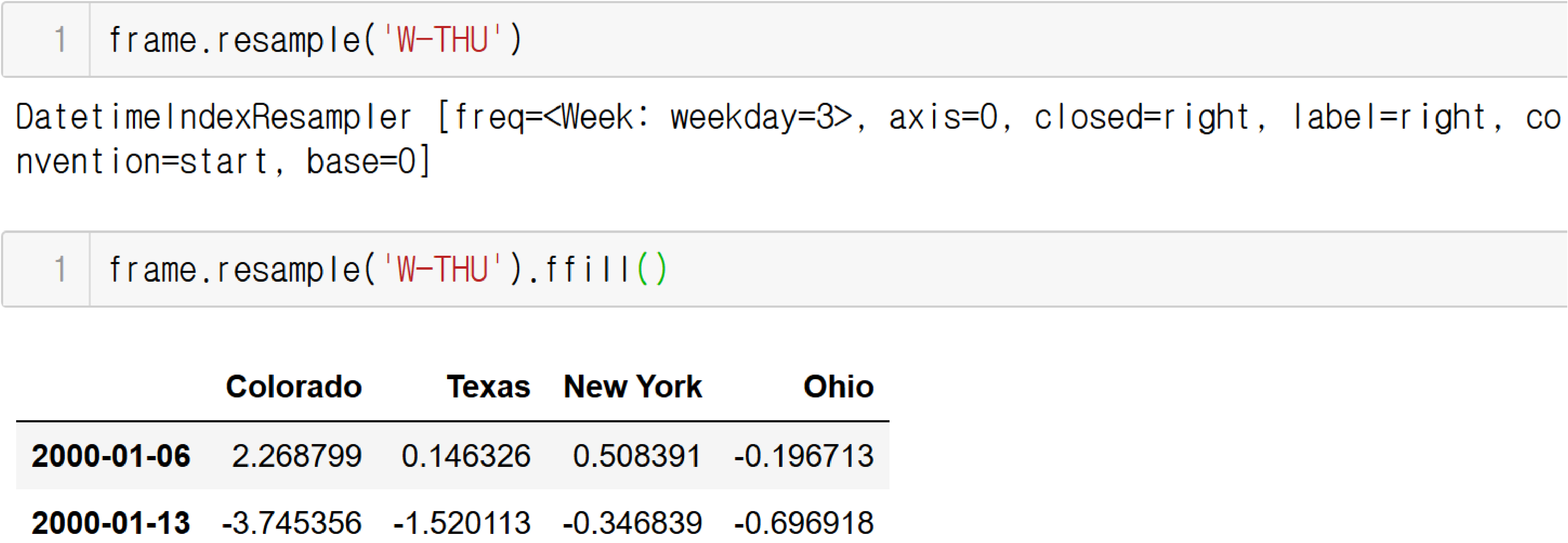


```python
frame.resample('D').ffill(limit=2)
```



	Colorado	Texas	New York	Ohio
2000-01-05	2.268799	0.146326	0.508391	-0.196713
2000-01-06	2.268799	0.146326	0.508391	-0.196713
2000-01-07	2.268799	0.146326	0.508391	-0.196713
2000-01-08	NaN	NaN	NaN	NaN
2000-01-09	NaN	NaN	NaN	NaN
2000-01-10	NaN	NaN	NaN	NaN
2000-01-11	NaN	NaN	NaN	NaN
2000-01-12	-3.745356	-1.520113	-0.346839	-0.696918

Upsampling and Interpolation



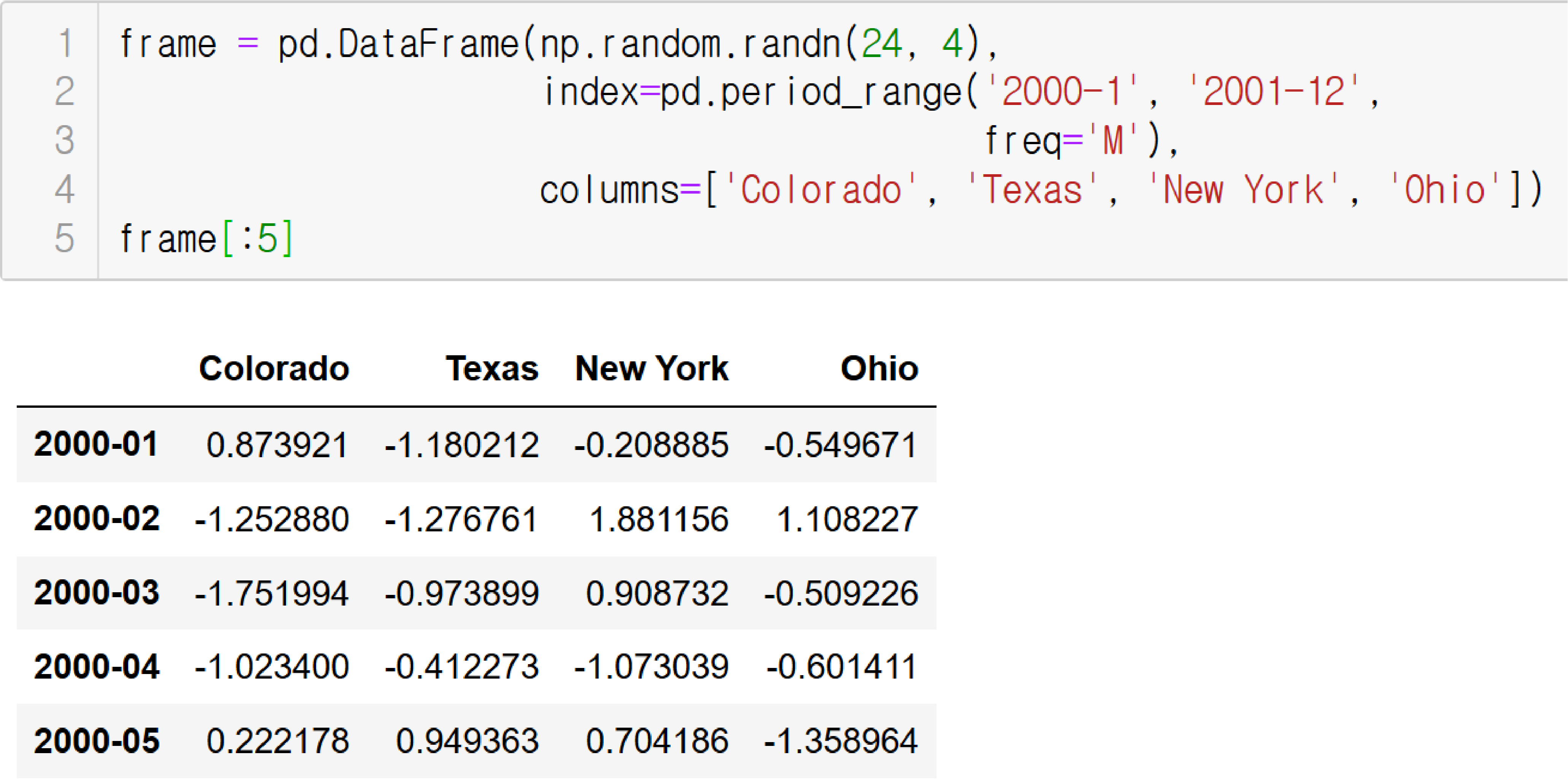
```python
frame.resample('W-THU')
```

```
DatetimeIndexResampler [freq=<Week: weekday=3>, axis=0, closed=right, label=right, co
nvention=start, base=0]
```

```python
frame.resample('W-THU').ffill()
```

	Colorado	Texas	New York	Ohio
2000-01-06	2.268799	0.146326	0.508391	-0.196713
2000-01-13	-3.745356	-1.520113	-0.346839	-0.696918

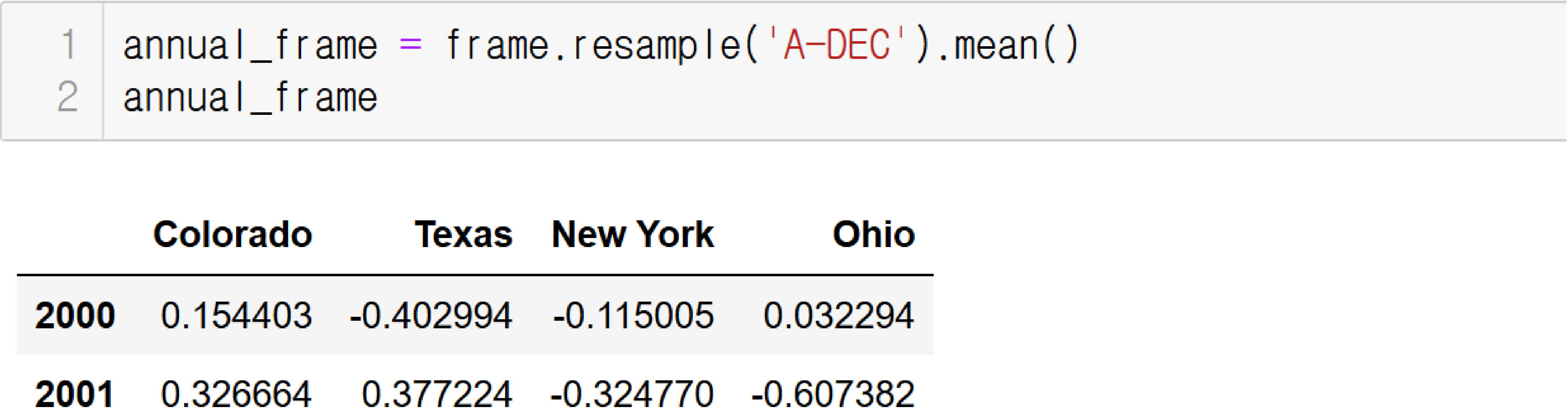
Resampling with Periods



```python
frame = pd.DataFrame(np.random.randn(24, 4),
                     index=pd.period_range('2000-1', '2001-12',
                                          freq='M'),
                     columns=['Colorado', 'Texas', 'New York', 'Ohio'])
frame[:5]
```

	Colorado	Texas	New York	Ohio
2000-01	0.873921	-1.180212	-0.208885	-0.549671
2000-02	-1.252880	-1.276761	1.881156	1.108227
2000-03	-1.751994	-0.973899	0.908732	-0.509226
2000-04	-1.023400	-0.412273	-1.073039	-0.601411
2000-05	0.222178	0.949363	0.704186	-1.358964

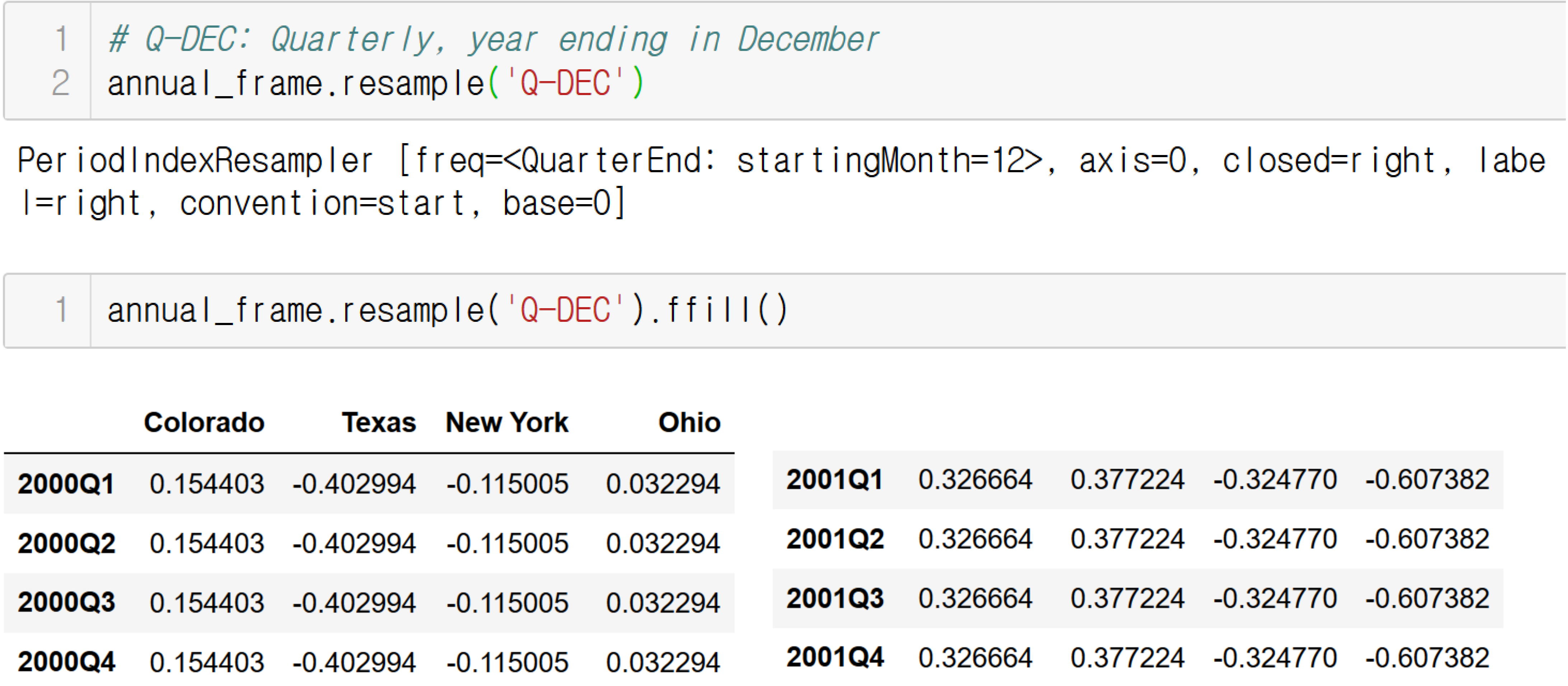
Resampling with Periods



```python
annual_frame = frame.resample('A-DEC').mean()
annual_frame
```

	Colorado	Texas	New York	Ohio
2000	0.154403	-0.402994	-0.115005	0.032294
2001	0.326664	0.377224	-0.324770	-0.607382

Resampling with Periods



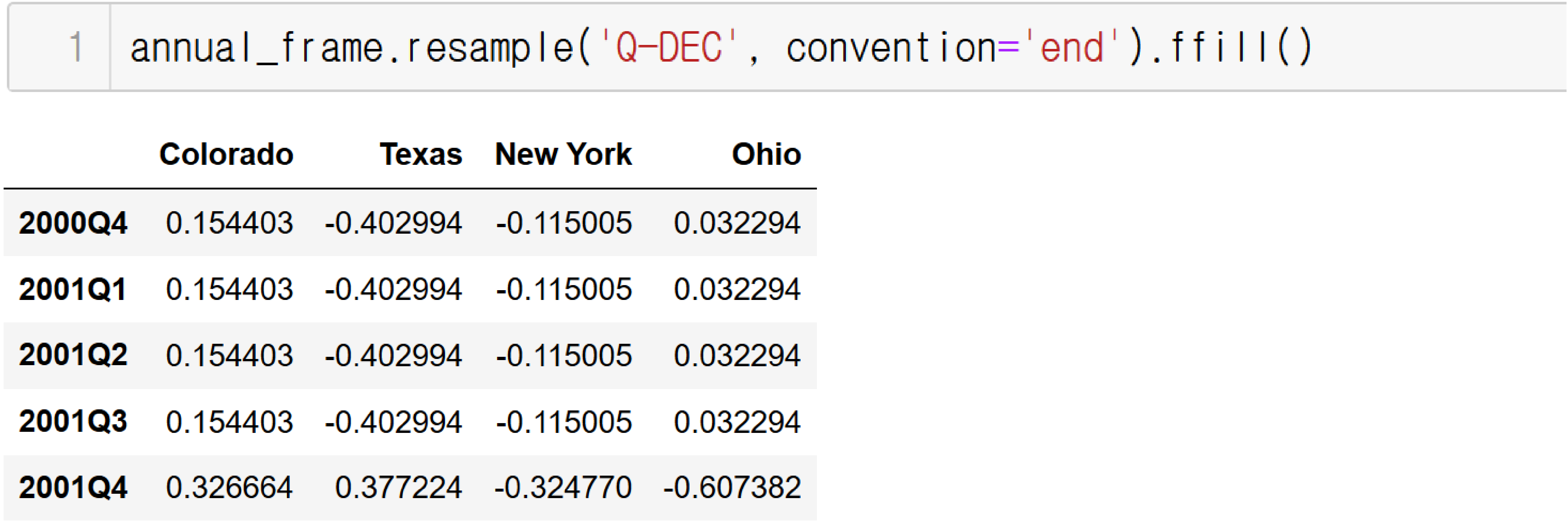
```python
# Q-DEC: Quarterly, year ending in December
annual_frame.resample('Q-DEC')
```

```
PeriodIndexResampler [freq=<QuarterEnd: startingMonth=12>, axis=0, closed=right, labe
l=right, convention=start, base=0]
```

```python
annual_frame.resample('Q-DEC').ffill()
```

	Colorado	Texas	New York	Ohio
2000Q1	0.154403	-0.402994	-0.115005	0.032294
2000Q2	0.154403	-0.402994	-0.115005	0.032294
2000Q3	0.154403	-0.402994	-0.115005	0.032294
2000Q4	0.154403	-0.402994	-0.115005	0.032294
2001Q1	0.326664	0.377224	-0.324770	-0.607382
2001Q2	0.326664	0.377224	-0.324770	-0.607382
2001Q3	0.326664	0.377224	-0.324770	-0.607382
2001Q4	0.326664	0.377224	-0.324770	-0.607382

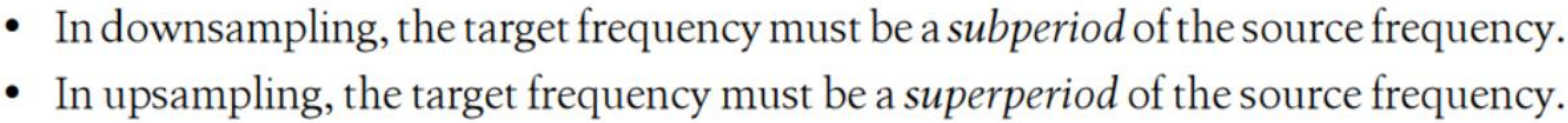
Resampling with Periods



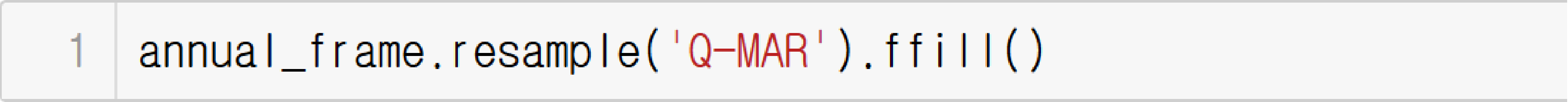
```python
annual_frame.resample('Q-DEC', convention='end').ffill()
```

	Colorado	Texas	New York	Ohio
2000Q4	0.154403	-0.402994	-0.115005	0.032294
2001Q1	0.154403	-0.402994	-0.115005	0.032294
2001Q2	0.154403	-0.402994	-0.115005	0.032294
2001Q3	0.154403	-0.402994	-0.115005	0.032294
2001Q4	0.326664	0.377224	-0.324770	-0.607382

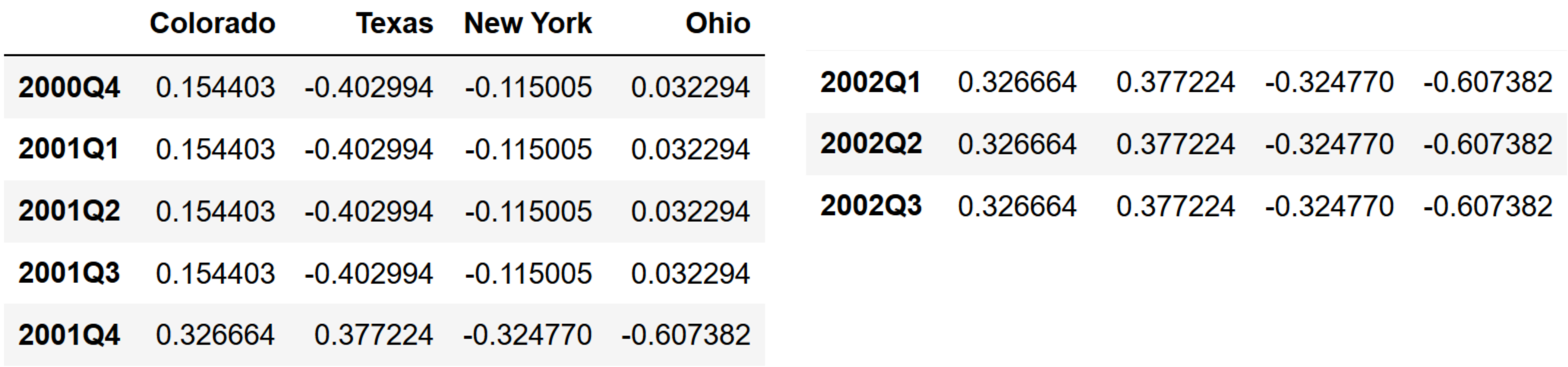
Resampling with Periods



- In downsampling, the target frequency must be a *subperiod* of the source frequency.
- In upsampling, the target frequency must be a *superperiod* of the source frequency.



```
annual_frame.resample('Q-MAR').ffill()
```



	Colorado	Texas	New York	Ohio
2000Q4	0.154403	-0.402994	-0.115005	0.032294
2001Q1	0.154403	-0.402994	-0.115005	0.032294
2001Q2	0.154403	-0.402994	-0.115005	0.032294
2001Q3	0.154403	-0.402994	-0.115005	0.032294
2001Q4	0.326664	0.377224	-0.324770	-0.607382
2002Q1	0.326664	0.377224	-0.324770	-0.607382
2002Q2	0.326664	0.377224	-0.324770	-0.607382
2002Q3	0.326664	0.377224	-0.324770	-0.607382