In [1]:

```
import numpy as np
import pandas as pd
import xarray as xr
from matplotlib import pyplot as plt
from statsmodels.tsa.seasonal import seasonal_decompose
import datetime as dt
import matplotlib.ticker as ticker
```

1. Global methane levels from 2002

1.1 Compute methane climatology for each month, and plot your results in 12 panels.

In [2]:

```
# Read nc files
Methane = xr.open_dataset("200301_202006-C3S-L3_GHG-PRODUCTS-OBS4MIPS-MERGED-v4.3.nc", engi
Methane
```

Out[2]:

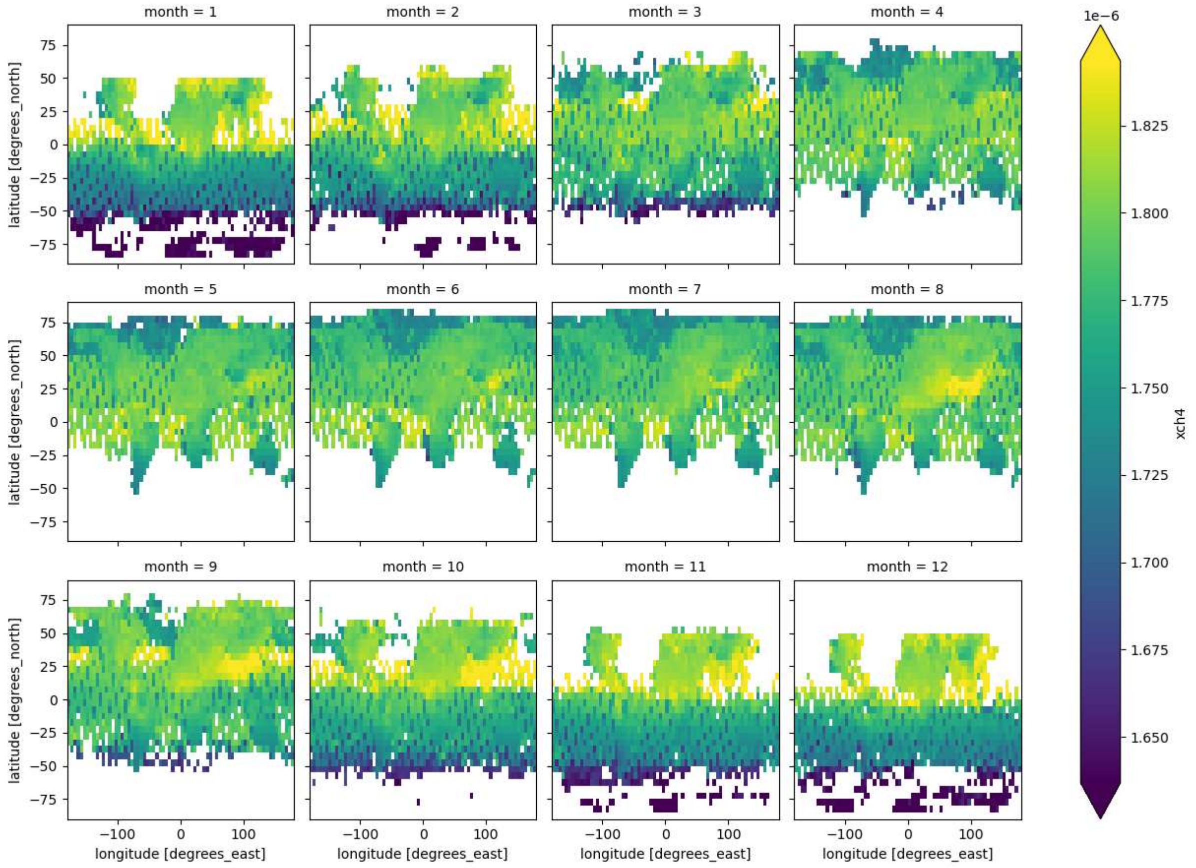
```
xarray.Dataset

► Dimensions:        (time: 210, bnds: 2, lat: 36, lon: 72, pressure: 10)

▼ Coordinates:
    time             (time)                   datetime64[ns] 2003-01-…
    lat              (lat)                           float64 -87.5 -8…
    lon              (lon)                           float64 -177.5 -…

▼ Data variables:
    time_bnds        (time, bnds)             datetime64[ns] ...
    lat_bnds         (lat, bnds)                     float64 ...
    lon_bnds         (lon, bnds)                     float64 ...
    pre              (pressure)                      float64 ...
    pre_bnds         (pressure, bnds)                float64 ...
    land_fraction    (lat, lon)                      float64 ...
    xch4             (time, lat, lon)                float32 ...
    xch4_nobs        (time, lat, lon)                float64 ...
    xch4_stderr      (time, lat, lon)                float32 ...
    xch4_stddev      (time, lat, lon)                float32 ...
    column_averag…   (time, pressure, lat, lon)      float32 ...
    vmr_profile_c…   (time, pressure, lat, lon)      float32 ...

► Attributes:  (28)
```

In [3]:

```
# Calculate the climatology
Methane_Mclim = Methane.xch4.groupby(Methane.time.dt.month).mean()
Methane_Mclim.plot(col="month", col_wrap=4,robust=True)
```

Out[3]:

```
<xarray.plot.facetgrid.FacetGrid at 0x173b5c99490>
```



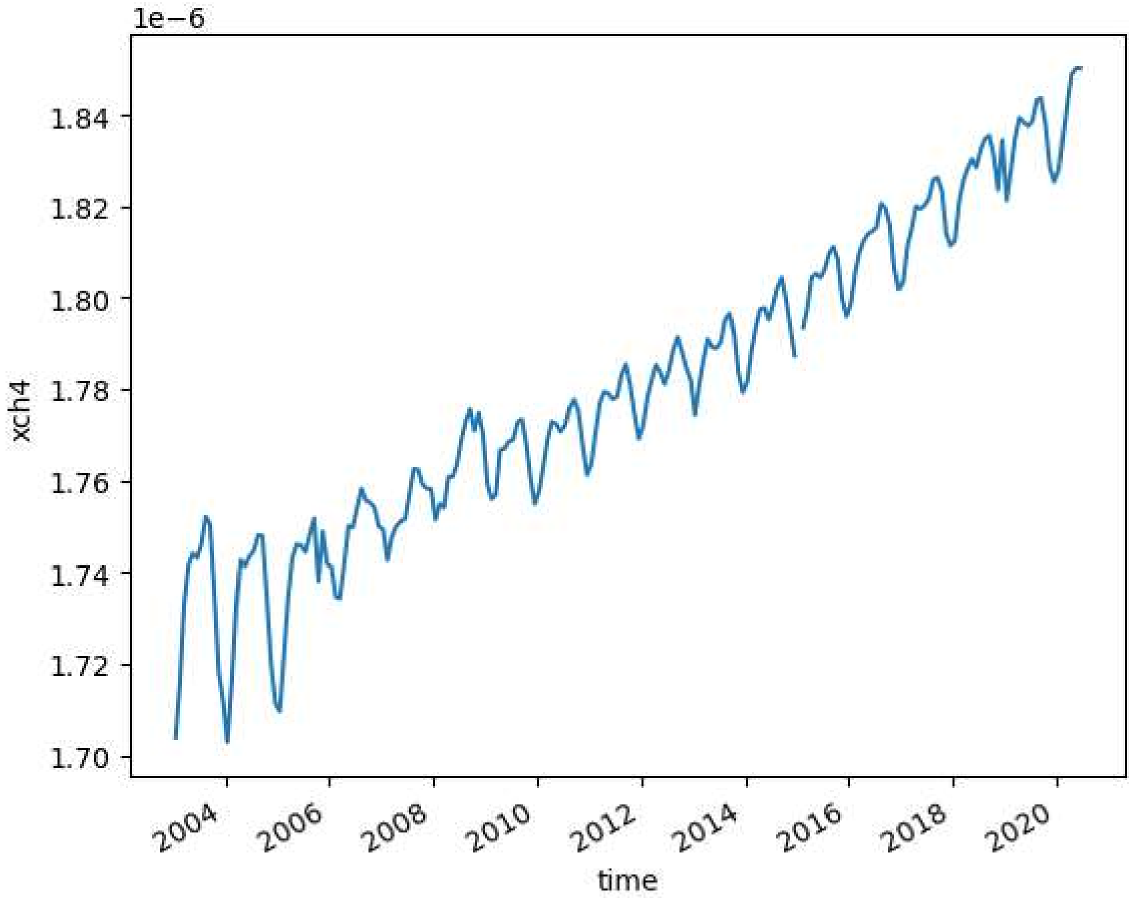
1.2 Plot globally-averaged methane from 2003-01 to 2020-06 as a time series. Describe your results. Check your plot with this one.

In [4]:

```
# globally-averaged methane
Methane.xch4.mean(dim=['lat', 'lon']).plot()
```

Out[4]:

```
[<matplotlib.lines.Line2D at 0x173bf073580>]
```

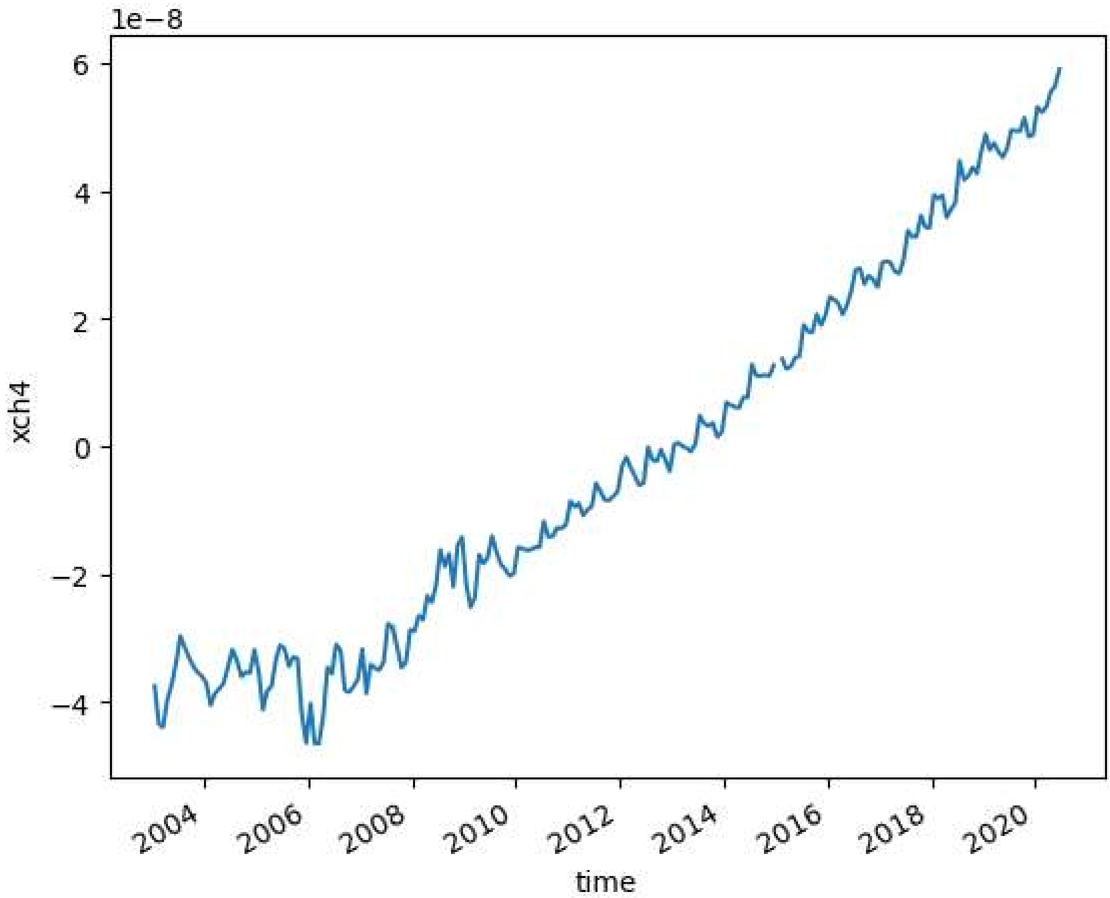


In [5]:

```
# deseasonalized methane levels

# Group data by month
group_data = Methane.xch4.groupby('time.month')

# Apply mean to grouped data, and then compute the anomaly
xch4_anom = group_data - group_data.mean(dim='time')
# xch4_anom
xch4_anom.mean(dim=['lat', 'lon']).plot()
```

Out[5]:

```
[<matplotlib.lines.Line2D at 0x173bd5401f0>]
```



1.3 Plot deseasonalized methane levels at point [15°S, 150°W] from 2003-01 to 2020-06 as a time series. Describe your results.

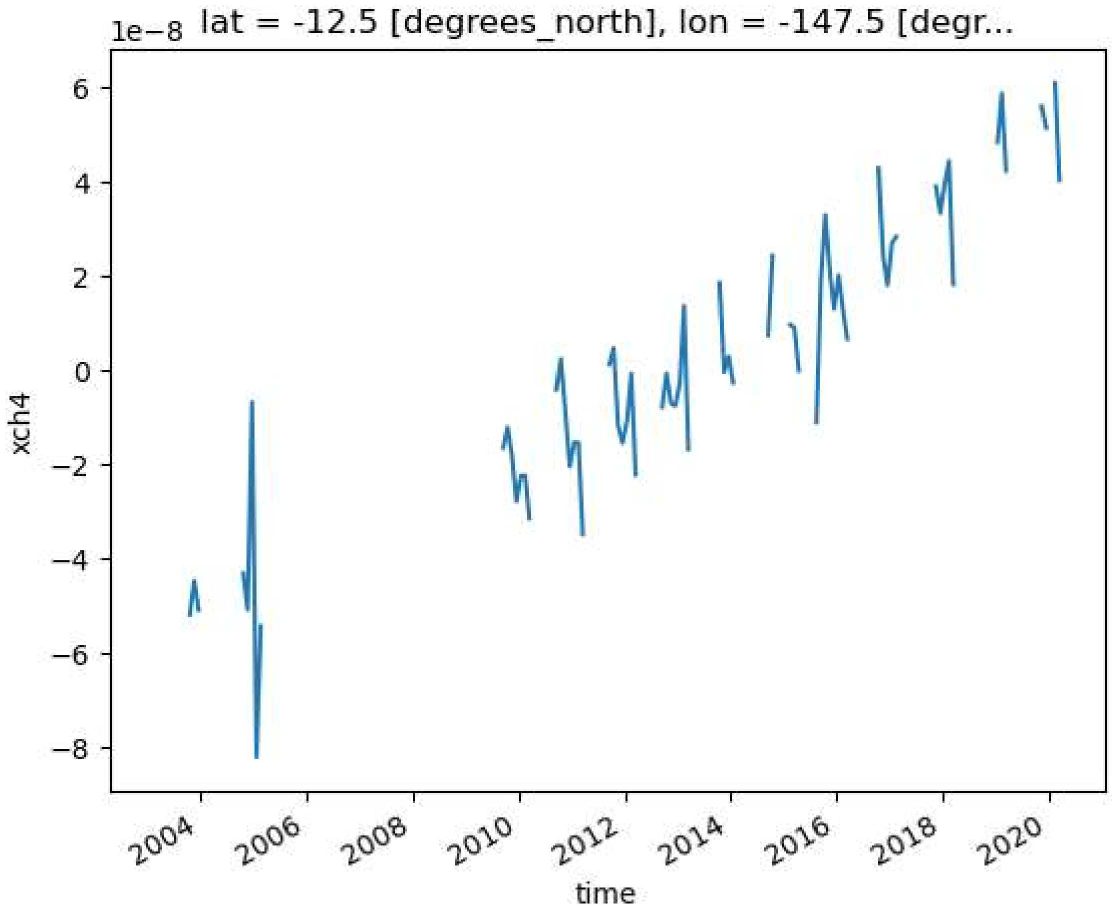
In [6]:

```
# Remove the seasonal cycle

# methane levels showed as anomalies
xch4_anom.sel(lon = -150, lat = -15,method = 'nearest').plot()
```

```
D:\ANACONDA\lib\site-packages\xarray\core\indexes.py:234: FutureWar
ning: Passing method to Float64Index.get_loc is deprecated and will
raise in a future version. Use index.get_indexer([item], method
=...) instead.
  indexer = self.index.get_loc(
D:\ANACONDA\lib\site-packages\xarray\core\indexes.py:234: FutureWar
ning: Passing method to Float64Index.get_loc is deprecated and will
raise in a future version. Use index.get_indexer([item], method
=...) instead.
  indexer = self.index.get_loc(
```

Out[6]:

```
[<matplotlib.lines.Line2D at 0x173bd44d220>]
```



2. Niño 3.4 index

In [7]:

```
# Read nc files
SST = xr.open_dataset("NOAA_NCDC_ERSST_v3b_SST.nc", engine="netcdf4")
SST
```

Out[7]:

```
xarray.Dataset

► Dimensions:      (lat: 89, lon: 180, time: 684)

▼ Coordinates:
    lat            (lat)                float32  -88.0 -86.0 -84.0 …
    lon            (lon)                float32  0.0 2.0 4.0 ... 35…
    time           (time)         datetime64[ns] 1960-01-15 ... 201…
▼ Data variables:
    sst            (time, lat, lon)     float32  ...
▼ Attributes:
    Conventions :  IRIDL
    source :       https://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCDC/.ERS
                   ST/.version3b/.sst/
    history :      extracted and cleaned by Ryan Abernathey for Research Co
                   mputing in Earth Science
```

In [8]:

```
# two regions one for better view and one for Niño 3.4 region.
SST_Niño3_4_Region_Show = SST.sel(lon = slice(100,360-60),       lat = slice(-60,60) )
SST_Niño3_4_Region      = SST.sel(lon = slice(360-170,360-120), lat = slice(-5,5)   )
```

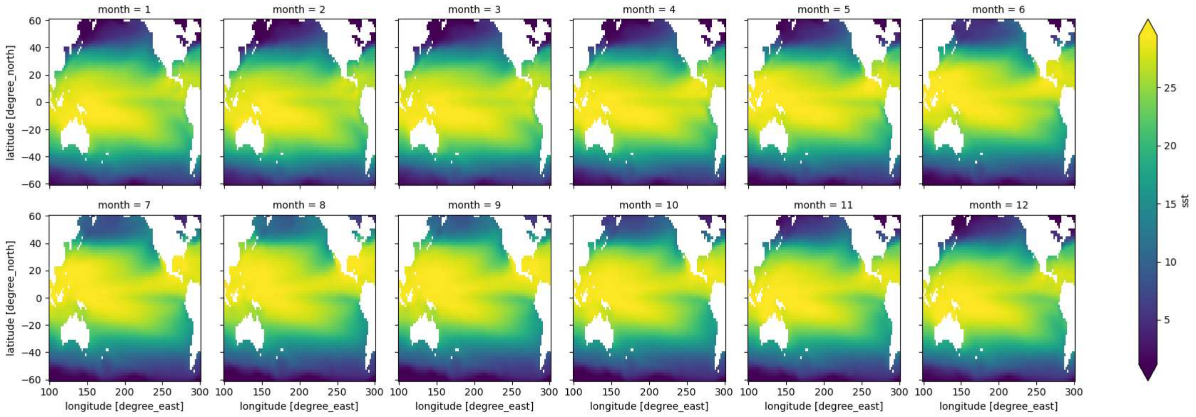
2.1 Compute monthly climatology for SST from Niño 3.4 region, and subtract climatology from SST time series to obtain anomalies.

In [9]:

```
# Calculate the climatology
SST_Niño3_4_Region_Show.sst.groupby('time.month').mean(dim='time').plot(col="month", col_wr

# This region is to show a better view of Niño 3.4 region
```

Out[9]:

<xarray.plot.facetgrid.FacetGrid at 0x173bd4dc220>

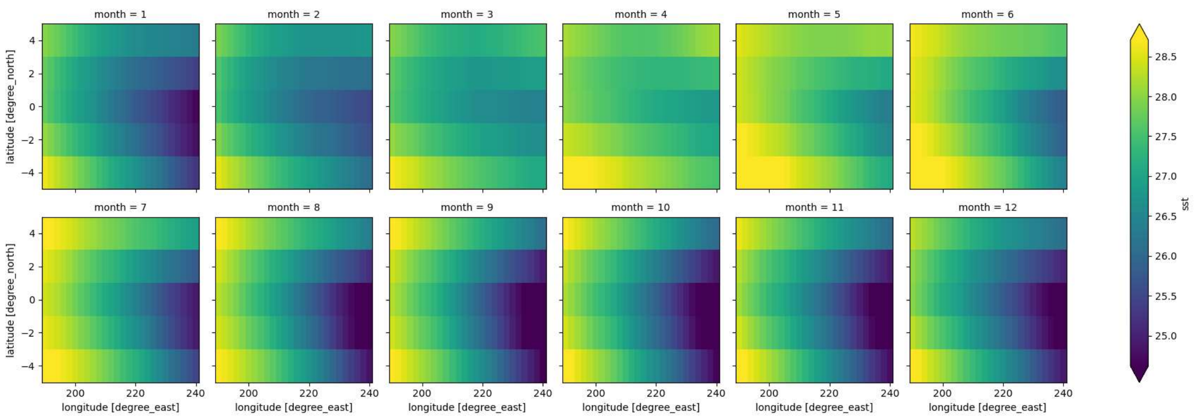


In [10]:

```
# This one is
SST_Niño3_4_Region.sst.groupby('time.month').mean(dim='time').plot(col="month", col_wrap=6,
```

Out[10]:

<xarray.plot.facetgrid.FacetGrid at 0x173bf411790>



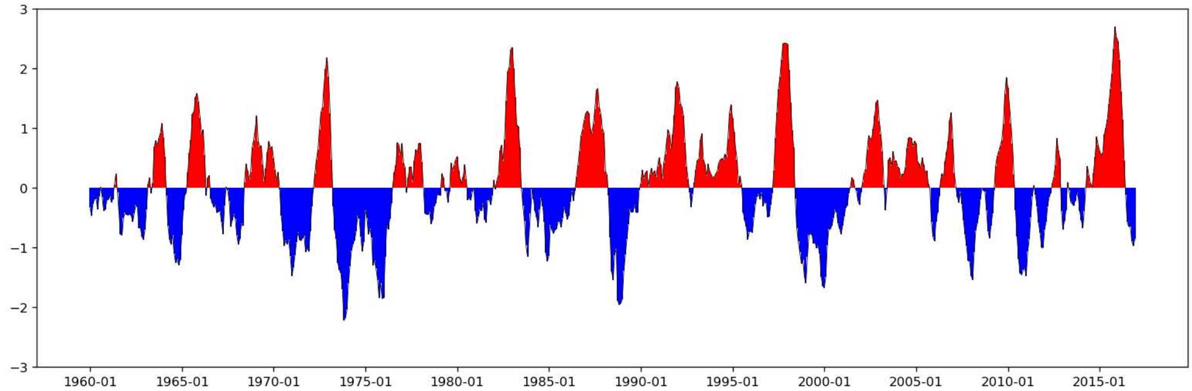
In [11]:

```
# Group data by month
SST_groupby      = SST_Niño3_4_Region.sst.groupby('time.month')
#SST_groupby_Show = SST_Niño3_4_Region_Show.sst.groupby('time.month')

# Apply mean to grouped data, and then compute the anomaly
SST_anom      = SST_groupby - SST_groupby.mean(dim='time')
#SST_anom_Show = SST_groupby_Show - SST_groupby_Show.mean(dim='time')

#
# SST_anom
```

2.2 Visualize the computed Niño 3.4.

In [12]:

```
# Time
timeX = SST_anom.sel(time=slice('1960','2016')).mean(dim=['lat', 'lon']).time.dt.strftime('

# Anomaly
heightH = SST_anom.sel(time=slice('1960','2016')).mean(dim=['lat', 'lon'])

# Draw plot
fig, ax = plt.subplots(1,1, figsize=(16,5), dpi=120)

# Red for positive blue for negative
colormat = np.where(heightH>0, 'r','b')

# line
ax.plot(timeX,heightH,'k-',linewidth=0.5 )

# bar plot
ax.bar(timeX,heightH,width = 1,color = colormat) # green dots

# ylim
ax.set_ylim(-3, 3)

# every five years
ax.xaxis.set_major_locator(ticker.MultipleLocator(base=60))
```



3.Explore a netCDF dataset

In [13]:

```
# Open CSR Grace Data
GraceCSR = xr.open_dataset("CSR_GRACE_GRACE-FO_RL06_Mascons_all-corrections_v02.nc", engine

# Open CSR Land Mask Data
GraceCSR_LandMask = xr.open_dataset("CSR_GRACE_GRACE-FO_RL06_Mascons_v02_LandMask.nc", engi
```

In [14]:

```
GraceCSR
```

Out[14]:

```
xarray.Dataset

► Dimensions:      (time: 212, timebound: 2, lon: 1440, lat: 720)

▼ Coordinates:
   time            (time)              float32 107.0 129.5 ... 7.502e+0…
   lon             (lon)               float32 0.125 0.375 0.625 ... 35…
   lat             (lat)               float32 -89.88 -89.62 ... 89.62 …

▼ Data variables:
   time_bounds     (time, timebound)   float32 ...
   lwe_thickness   (time, lat, lon)    float32 ...

► Attributes: (58)
```

In [15]:

```
# Change the time dimention.

# Day.txt viewed by Arcmap and summarized by myself manually
day = pd.read_csv("day.txt",header = None)
time = pd.to_datetime(day[0]).to_numpy()

# time dimention changed
GraceCSR.coords['time'] = ('time',time)
```

In [16]:

```
# Add a new variable as land mask.
GraceCSR['island'] = GraceCSR_LandMask.LO_val
GraceCSR
```

Out[16]:

```
xarray.Dataset

► Dimensions:      (time: 212, timebound: 2, lon: 1440, lat: 720)

▼ Coordinates:

  time          (time)              datetime64[ns] 2002-04-01 ... 20...
  lon           (lon)               float32 0.125 0.375 0.625...
  lat           (lat)               float32 -89.88 -89.62 ....…

▼ Data variables:

  time_bounds   (time, timebound)   float32 94.0 120.0 ... 7....
  lwe_thickness (time, lat, lon)    float32 ...
  island        (lat, lon)          float32 ...

► Attributes:  (58)
```

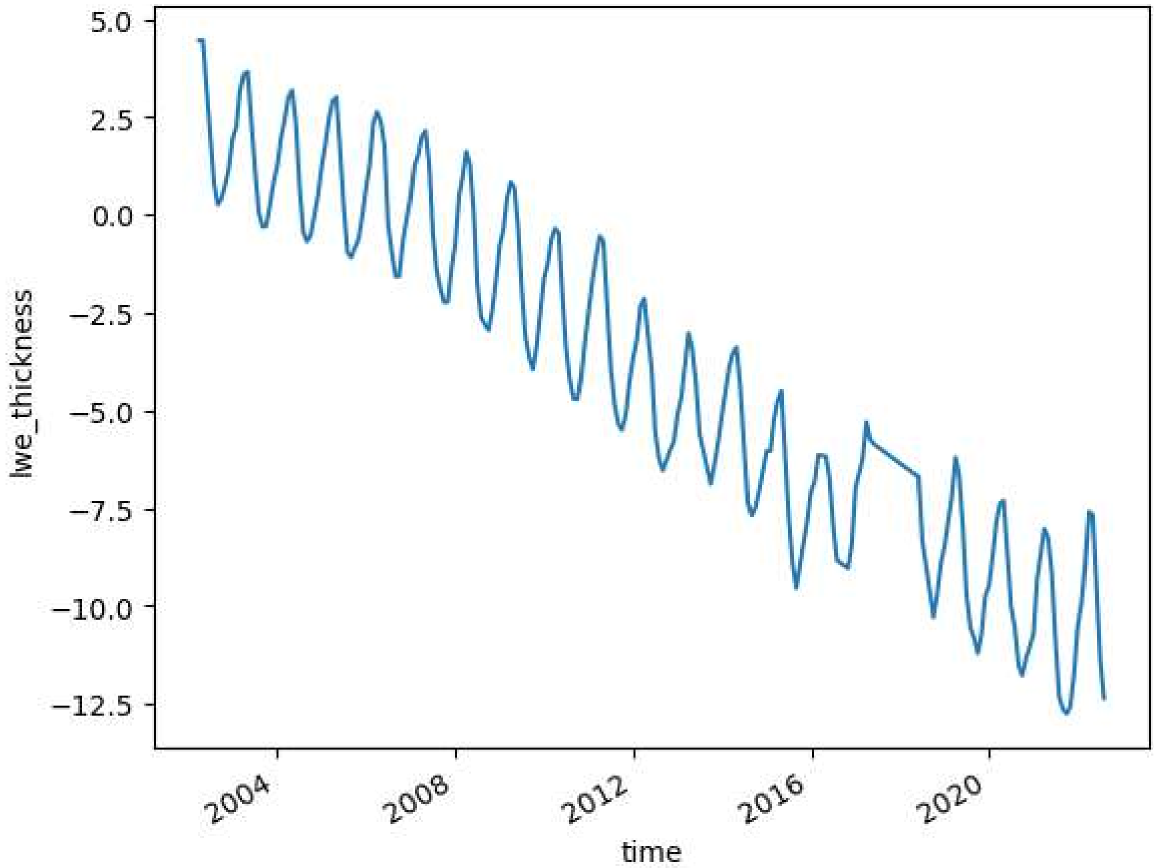
3.1 Plot a time series of a certain variable with monthly seasonal cycle removed.

In [17]:

```
# Time series of lwe_thickness
GraceCSR.lwe_thickness.where(GraceCSR.island ==1).mean(dim = ['lat','lon']).plot()
```

Out[17]:

```
[<matplotlib.lines.Line2D at 0x173c1cbafd0>]
```

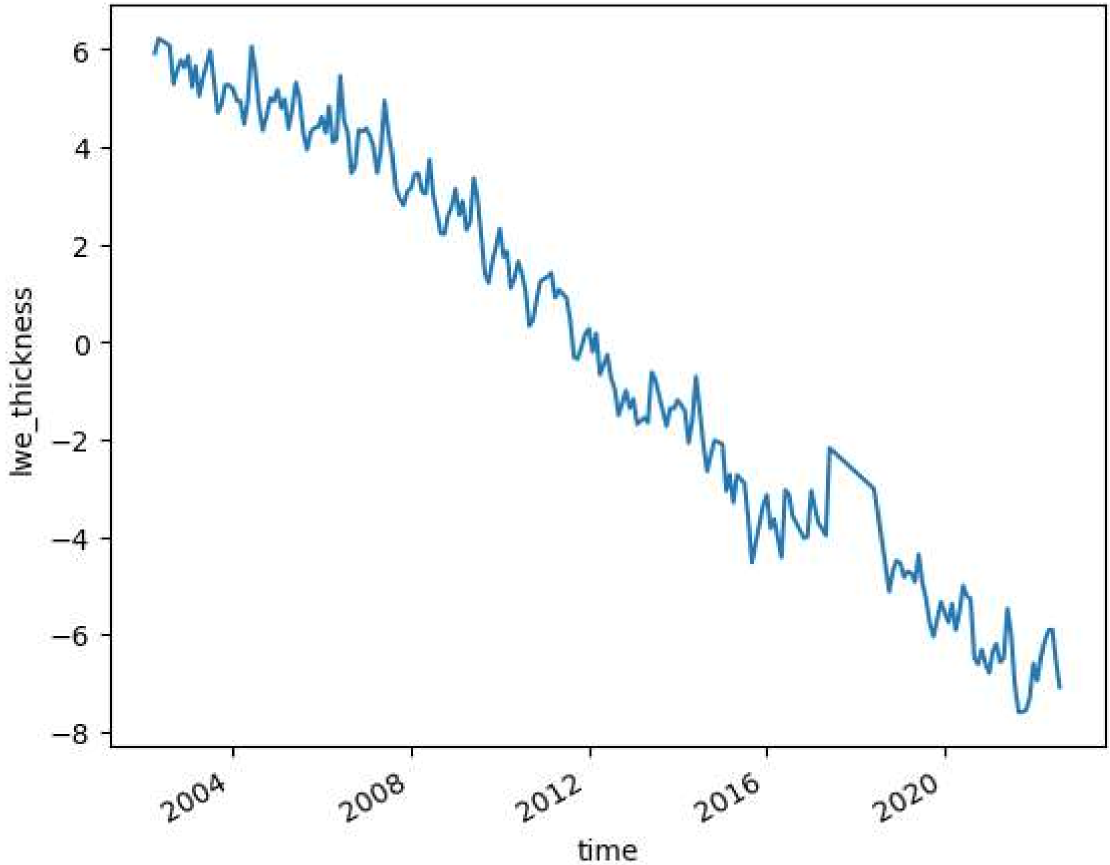


In [18]:

```
# with monthly seasonal cycle removed.

# Group data by month
group_data_CSR = GraceCSR.lwe_thickness.groupby('time.month')

# Apply mean to grouped data, and then compute the anomaly
CSR_anom = group_data_CSR - group_data_CSR.mean(dim='time')

CSR_anom.where(GraceCSR.island ==1).mean(dim = ['lat','lon']).plot()
```

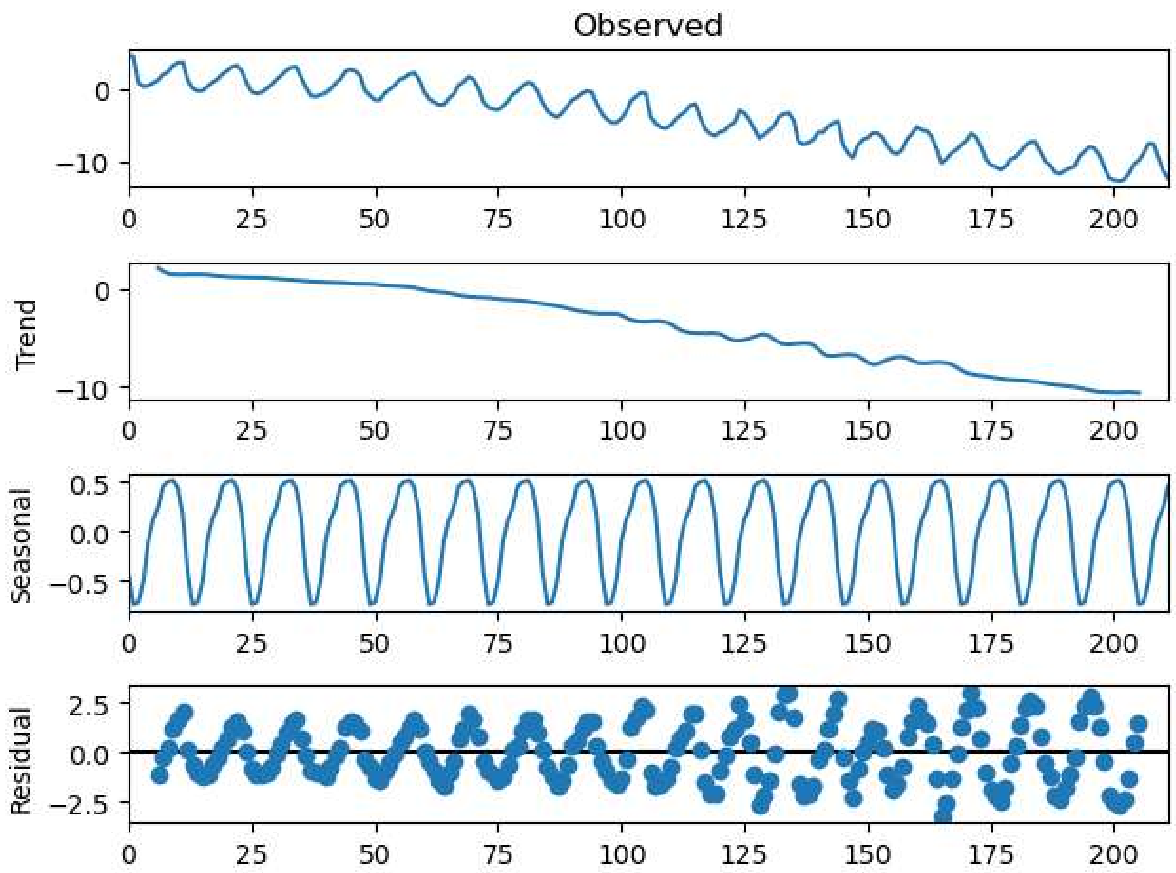
Out[18]:

```
[<matplotlib.lines.Line2D at 0x173c17ffca0>]
```



In [23]:

```
# Actually this is not true because the time series is not seriously continuous
decompose_data = seasonal_decompose(GraceCSR.lwe_thickness.where(GraceCSR.island ==1).mean(
decompose_data.plot();
```



3.2 Make at least 5 different plots using the dataset.

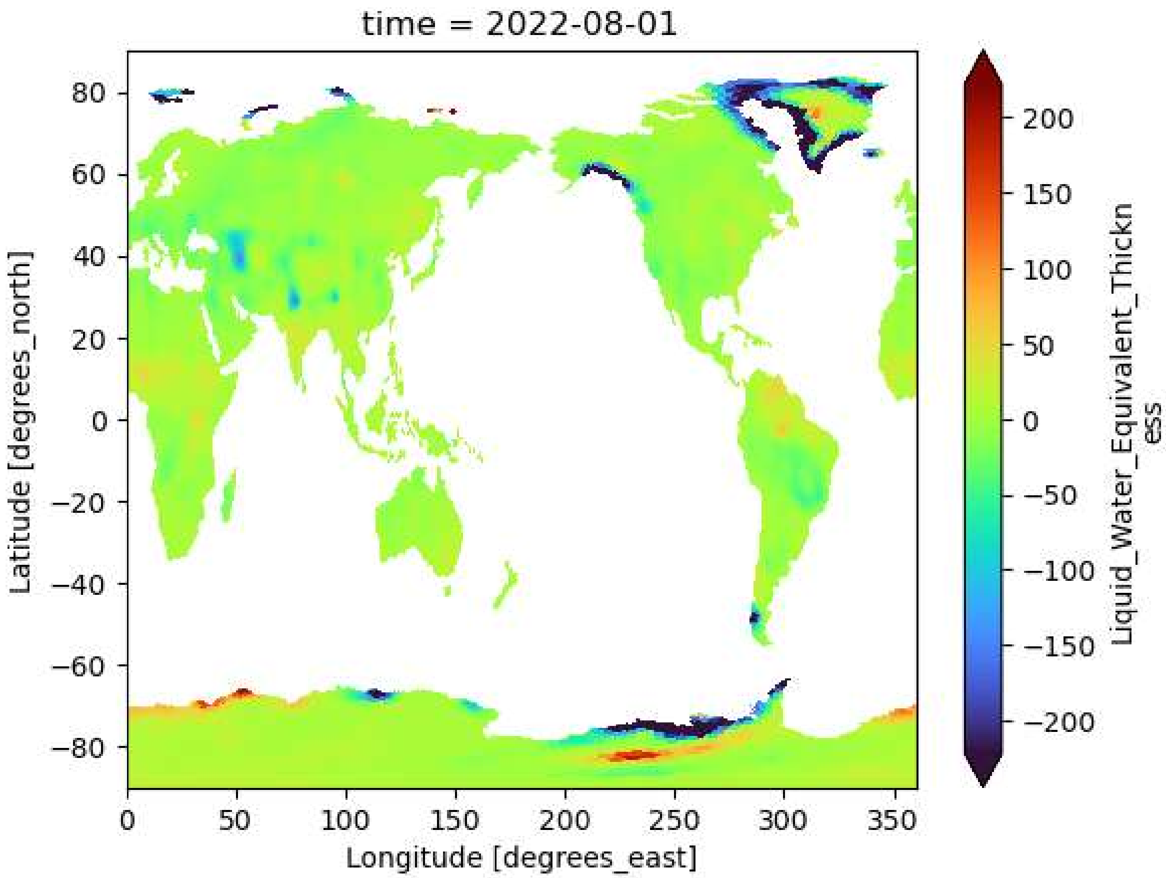
3.2.1

In [24]:

```
# Latest month for land
GraceCSR.lwe_thickness.where(GraceCSR.island == 1).isel(time=-1).plot(robust = True,cmap='t
```

Out[24]:

```
<matplotlib.collections.QuadMesh at 0x173c30bc400>
```



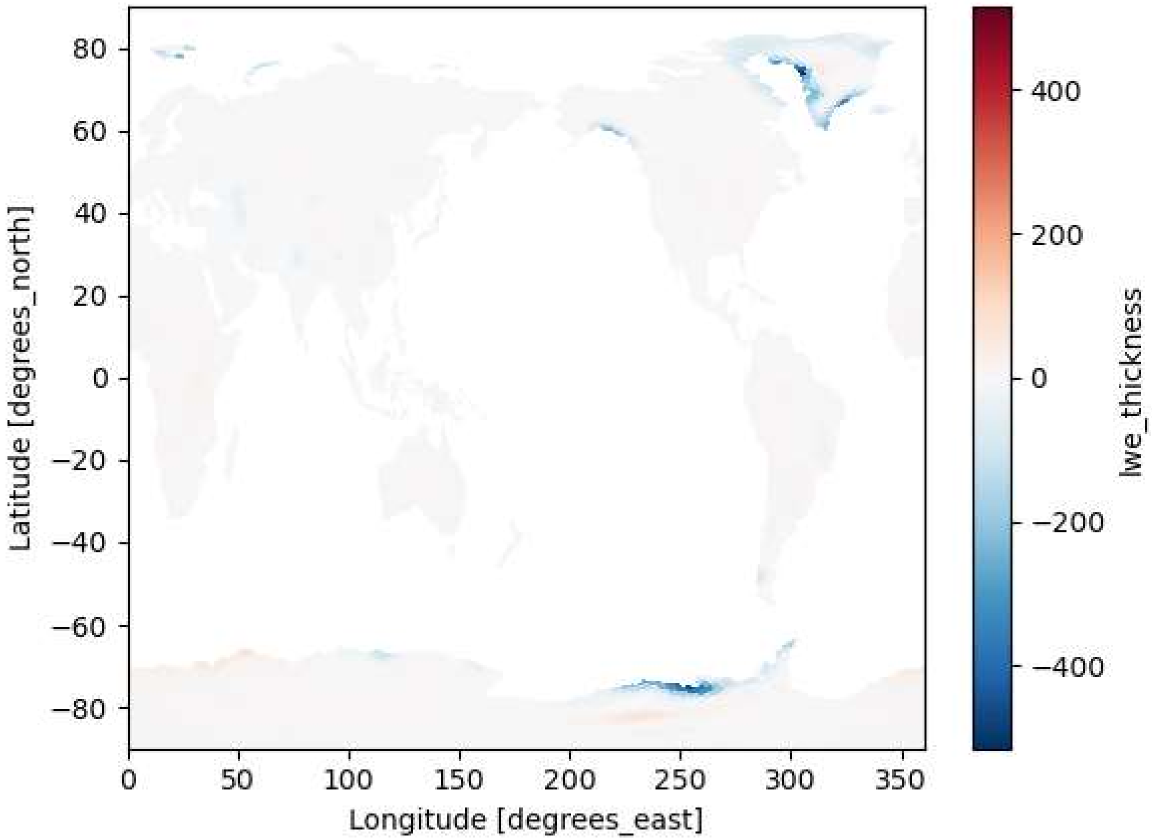
3.2.2

In [25]:

```
# Time mean
GraceCSR.lwe_thickness.where(GraceCSR.island == 1).mean(dim = 'time').plot()
```

Out[25]:

```
<matplotlib.collections.QuadMesh at 0x173c3518d00>
```



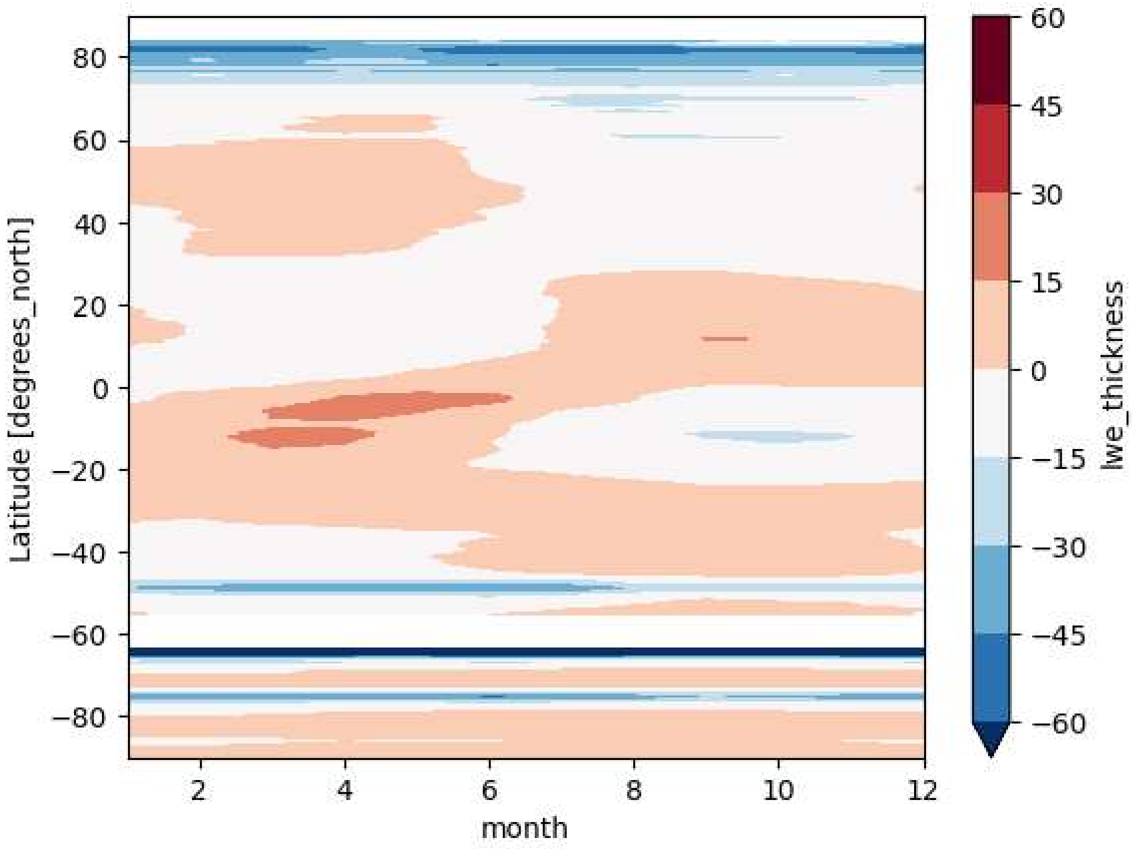
3.2.3

In [26]:

```
#vPlot zonal mean climatology for land
CSR_clim = GraceCSR.lwe_thickness.where(GraceCSR.island ==1).groupby('time.month').mean()

CSR_clim.mean(dim='lon').plot.contourf(x='month',
                                        levels=10, robust = True)#vmin=-5, vmax=35)
```

Out[26]:

<matplotlib.contour.QuadContourSet at 0x173c37480d0>



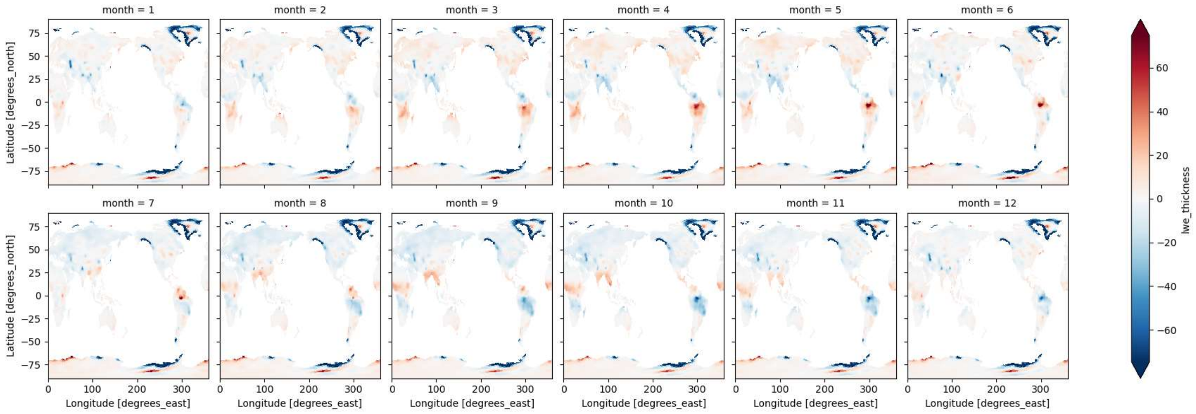
3.2.4

In [27]:

```
# Plot climatology
GraceCSR.lwe_thickness.where(GraceCSR.island ==1).groupby('time.month').mean(dim='time').pl
```

Out[27]:

```
<xarray.plot.facetgrid.FacetGrid at 0x173c35a87c0>
```



3.2.5

In [28]:

```
# Plot climatology at a specific point (My hometown Yibin)
CSR_clim.sel(lon=104, lat=28, method='nearest').plot()
```

```
D:\ANACONDA\lib\site-packages\xarray\core\indexes.py:234: FutureWar
ning: Passing method to Float64Index.get_loc is deprecated and will
raise in a future version. Use index.get_indexer([item], method
=...) instead.
  indexer = self.index.get_loc(
D:\ANACONDA\lib\site-packages\xarray\core\indexes.py:234: FutureWar
ning: Passing method to Float64Index.get_loc is deprecated and will
raise in a future version. Use index.get_indexer([item], method
=...) instead.
  indexer = self.index.get_loc(
```

Out[28]:

```
[<matplotlib.lines.Line2D at 0x173c7db9d60>]
```