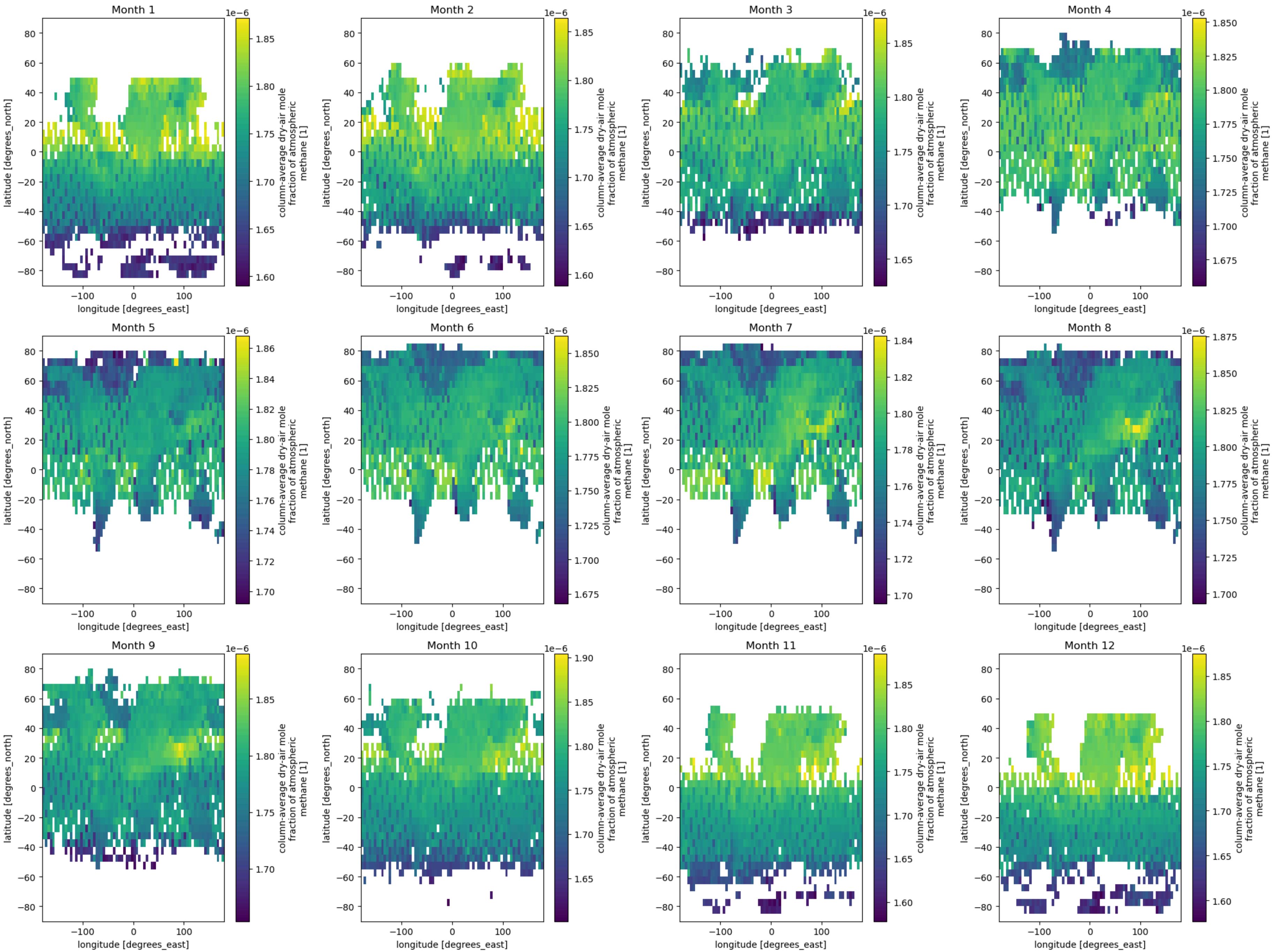
In [ ]:

```
#1.1. Global methane levels from 2002
#1.1.Compute methane climatology for each month, and plot your results in 12 panels.
```

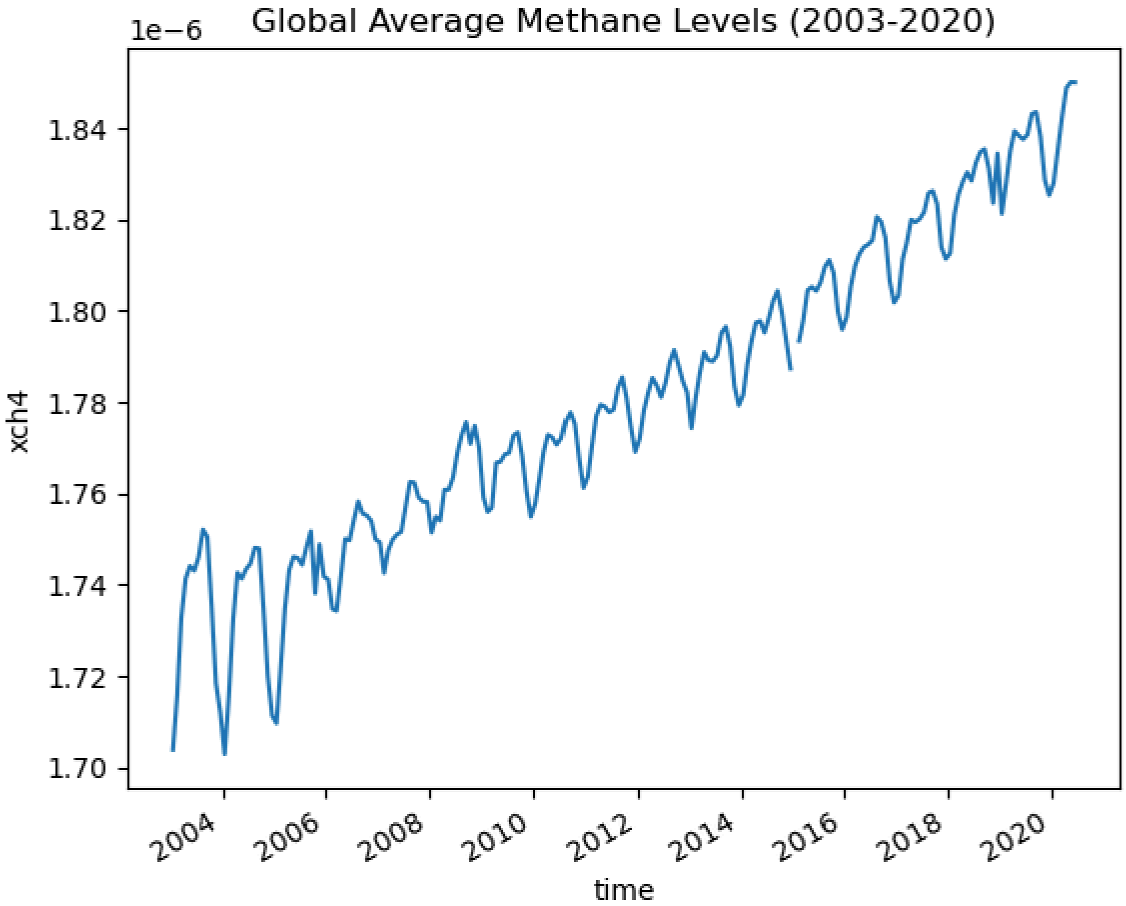
In [5]:

```
#使用xarray读取netCDF4文件。
#计算每个月的甲烷平均值。
#使用matplotlib绘制12个图，每个图代表一个月的甲烷。
import xarray as xr
import matplotlib.pyplot as plt
# 读取数据
ds = xr.open_dataset('D:/GitKraken/ese5023/assignment/assignment3/200301_202006-C3S-L3_GHG-PRODUCTS-OBS4MIPS-MERGED-v4.3.nc',
ds
# Compute methane climatology for each month
ch4_climatology = ds['xch4'].groupby('time.month').mean('time')

# 绘制12 panels
fig, axes = plt.subplots(3, 4, figsize=(20, 15))
for i, ax in enumerate(axes.flat):
    ch4_climatology.isel(month=i).plot(ax=ax)
    ax.set_title(f'Month {i+1}')
plt.tight_layout()
plt.show()
```



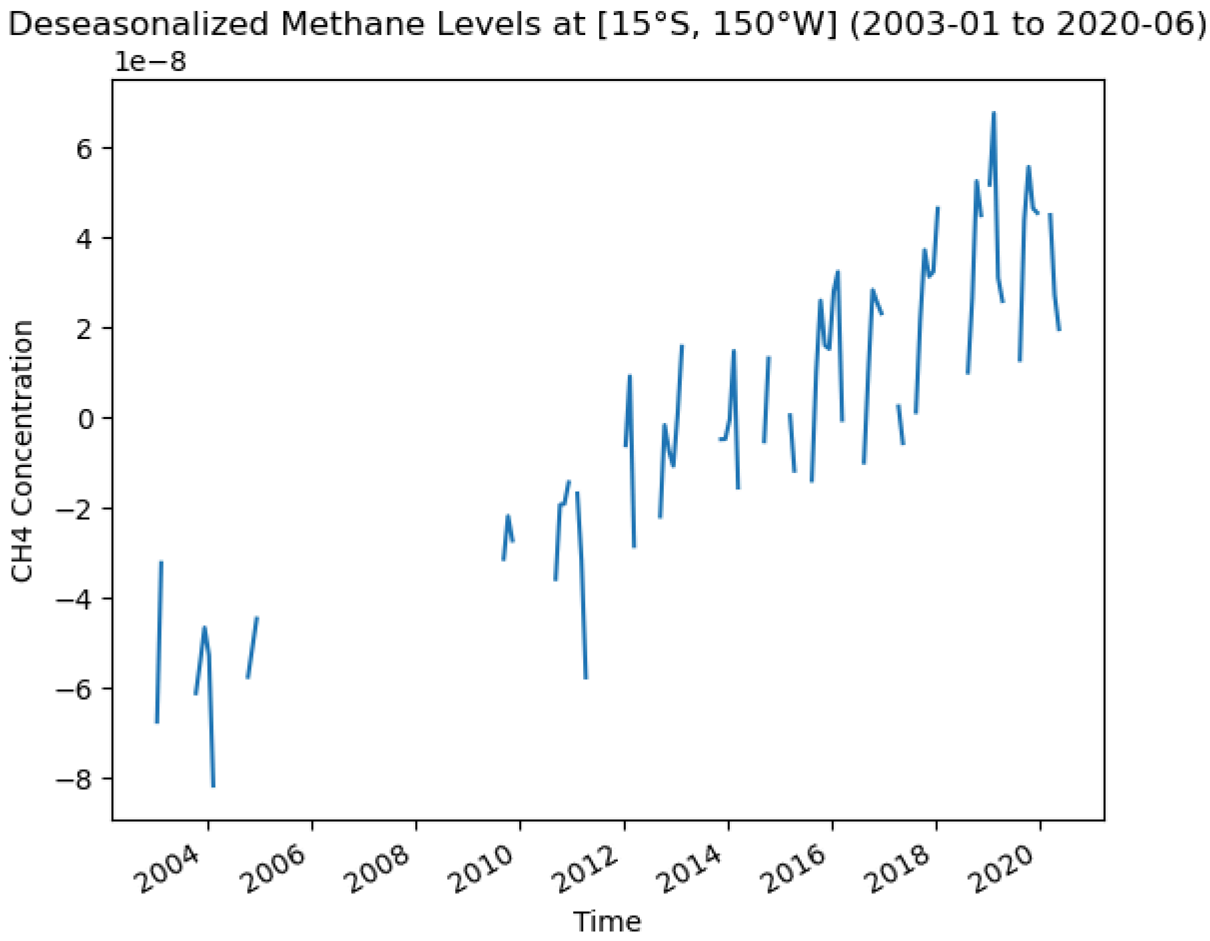
Month 1
Month 2
Month 3
Month 4
Month 5
Month 6
Month 7
Month 8
Month 9
Month 10
Month 11
Month 12
latitude [degrees_north]
longitude [degrees_east]
column-average dry-air mole fraction of atmospheric methane [1]
1e−6

In [3]:
```
#1.2  Plot globally-averaged methane from 2003-01 to 2020-06 as a time series. Describe your results. Check your plot with thi
# 计算全球平均甲烷
global_ch4 = ds['xch4'].mean(['lon', 'lat'])

# 绘制时间序列
global_ch4.plot()
plt.title('Global Average Methane Levels (2003-2020)')
plt.show()
#全球大气甲烷平均值逐年增加，年内月平均值呈锯齿状/波浪状先升高再下降。
```



In [7]:
```
#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
#计算点[15°S, 150°W]的甲烷水平。
```

```
#去除季节性周期。
#绘制时间序列图。
# 使用sel方法和method='nearest'来选择最接近的数据
point_ch4 = ds['xch4'].sel(lat=-15, lon=150, method='nearest')
point_ch4
# 检查是否有非nan的数据
if point_ch4.notnull().any():
    # 去除季节性周期
    deseasonalized_ch4 = point_ch4.groupby('time.month') - point_ch4.groupby('time.month').mean(dim='time')

    # 绘制时间序列图
    deseasonalized_ch4.plot()
    plt.title('Deseasonalized Methane Levels at [15°S, 150°W] (2003-01 to 2020-06)')
    plt.xlabel('Time')
    plt.ylabel('CH4 Concentration')
    plt.show()
else:
    print("No valid data to plot.")
```



In [9]:

```
#2 Niño 3.4 index
#2.1 Compute monthly climatology for SST from Niño 3.4 region, and subtract climatology from SST time series to obtain anomali
#读取SST数据。
#计算尼诺3.4区域的SST monthly climatology。
#从SST时间序列中减去气climatology以获得异常值。

# 读取SST数据
sst_ds = xr.open_dataset('D:/GitKraken/ese5023/assignment/assignment3/NOAA_NCDC_ERSST_v3b_SST.nc', engine="netcdf4")
sst_ds
# 定义尼诺3.4区域
nino34 = sst_ds.sst.sel(lat=slice(-5, 5), lon=slice(170, 120))
```

```python
nino34
# 计算monthly climatology
sst_climatology = nino34.groupby('time.month').mean('time')
sst_climatology
# 获取异常值
sst_anomalies = nino34.groupby('time.month') - sst_climatology
sst_anomalies
```

Out[9]: xarray.DataArray 'sst' (**time**: 684, **lat**: 5, **lon**: 0)

array([], shape=(684, 5, 0), dtype=float32)

▼ Coordinates:

lat	(lat)	float32	-4.0 -2.0 0.0 2.0 4.0
lon	(lon)	float32	
time	(time)	datetime64[ns]	1960-01-15 ... 2016-12-15
month	(time)	int64	1 2 3 4 5 6 7 ... 6 7 8 9 10 11 12

► Indexes: (3)

► Attributes: (0)

In [21]:

```python
#2.1Visualize the computed Niño 3.4. Your plot should look similar to this one.
# 读取SST数据
sst_ds = xr.open_dataset('D:/GitKraken/ese5023/assignment/assignment3/NOAA_NCDC_ERSST_v3b_SST.nc', engine="netcdf4")
sst_ds
# 定义尼诺3.4区域
nino34 = sst_ds.sst.sel(lat=slice(-5, 5), lon=slice(190, 240))
nino34
# 计算monthly climatology
sst_climatology = nino34.groupby('time.month').mean('time')
sst_climatology
# 获取异常值
sst_anomalies = nino34.groupby('time.month') - sst_climatology
sst_anomalies
```

Out[21]: xarray.DataArray 'sst' (**time**: 684, **lat**: 5, **lon**: 26)

```
array([[[-0.43157768, -0.41846275, -0.39795303, ..., -0.2116642 ,
         -0.23776245, -0.24401474],
        [-0.41259003, -0.4067192 , -0.3875141 , ..., -0.52064896,
         -0.5346451 , -0.51997185],
        [-0.40932274, -0.39743805, -0.36237717, ..., -0.6373882 ,
         -0.6171951 , -0.583725  ],
        [-0.4140854 , -0.37909317, -0.3215618 , ..., -0.43292618,
         -0.38404274, -0.3352623 ],
        [-0.5043678 , -0.43894005, -0.3710251 , ..., -0.17453575,
         -0.11044502, -0.06918144]],

       [[-0.5374584 , -0.52739716, -0.50823593, ..., -0.40254593,
         -0.44382668, -0.45287704],
        [-0.55093956, -0.539135  , -0.51673317, ..., -0.6660595 ,
         -0.7127285 , -0.710968  ],
        [-0.61242104, -0.5959244 , -0.5572338 , ..., -0.7235069 ,
         -0.7326374 , -0.73106194],
        [-0.6798363 , -0.6483364 , -0.5889931 , ..., -0.5397434 ,
         -0.50793266, -0.49977684],
        [-0.7830448 , -0.7286701 , -0.6683655 , ..., -0.33967972,
...
         -0.2555828 , -0.13972664],
        [-0.989378  , -1.0497723 , -1.0954857 , ..., -0.86087227,
         -0.7690697 , -0.65498734],
        [-1.1887245 , -1.252285  , -1.3029232 , ..., -1.0460625 ,
         -0.9661274 , -0.8785801 ],
        [-1.002367  , -1.0756893 , -1.1325111 , ..., -0.7207298 ,
         -0.6597252 , -0.5900669 ],
```

```
       [-0.5770798 , -0.65514374, -0.72174263, ..., -0.4353485 ,
        -0.36265945, -0.28103828]],

      [[-0.3578701 , -0.41542053, -0.47110367, ..., -0.2400589 ,
        -0.1464405 , -0.03788376],
       [-0.7678585 , -0.83501625, -0.9024124 , ..., -0.727829  ,
        -0.61603355, -0.48027992],
       [-0.96187973, -1.0445309 , -1.1224213 , ..., -0.9327831 ,
        -0.81235695, -0.6655674 ],
       [-0.82112694, -0.9206734 , -1.0085506 , ..., -0.6531601 ,
        -0.5626869 , -0.4374504 ],
       [-0.4864292 , -0.5823746 , -0.6702862 , ..., -0.36221695,
        -0.30041504, -0.1987915 ]]], dtype=float32)
```

▼ Coordinates:

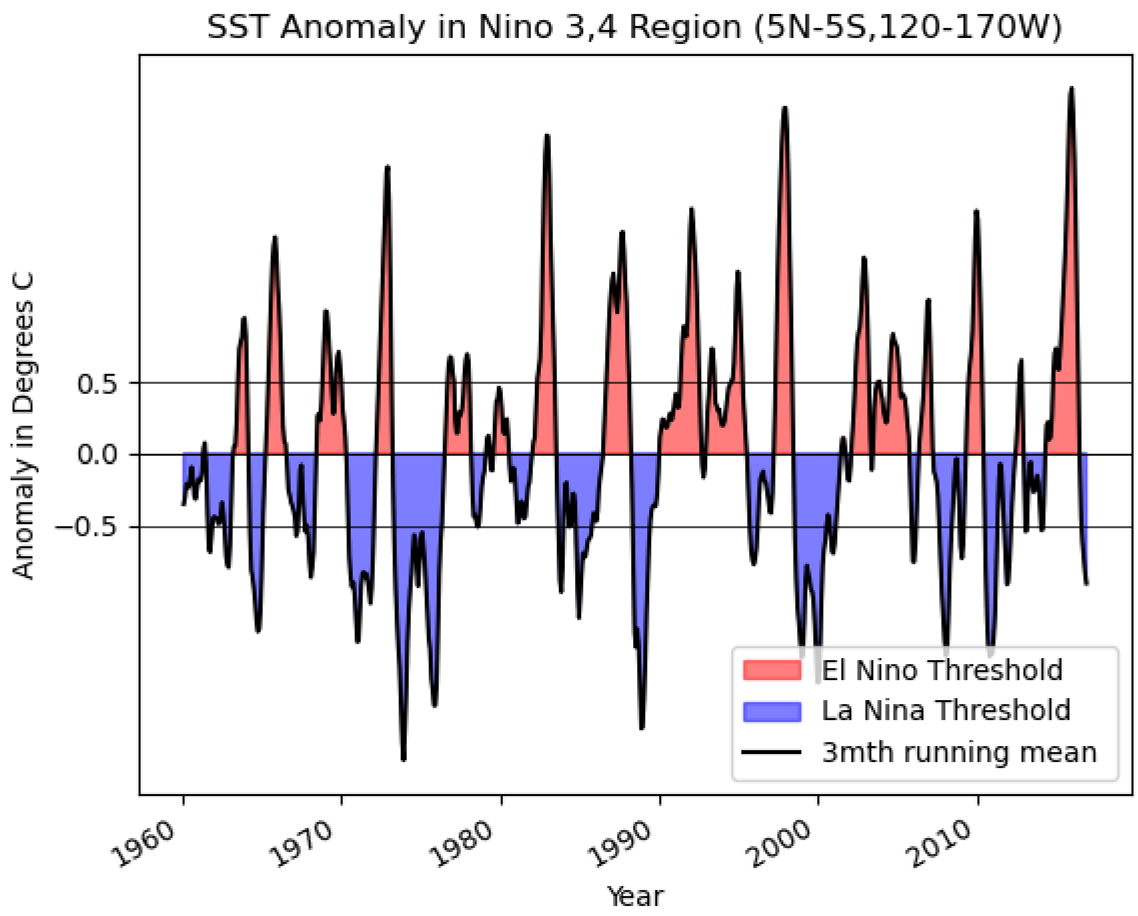
lat	(lat)	float32	-4.0 -2.0 0.0 2.0 4.0
lon	(lon)	float32	190.0 192.0 194.0 ... 238.0 240.0
time	(time)	datetime64[ns]	1960-01-15 ... 2016-12-15
month	(time)	int64	1 2 3 4 5 6 7 ... 6 7 8 9 10 11 12

► Indexes: (3)

► Attributes: (0)

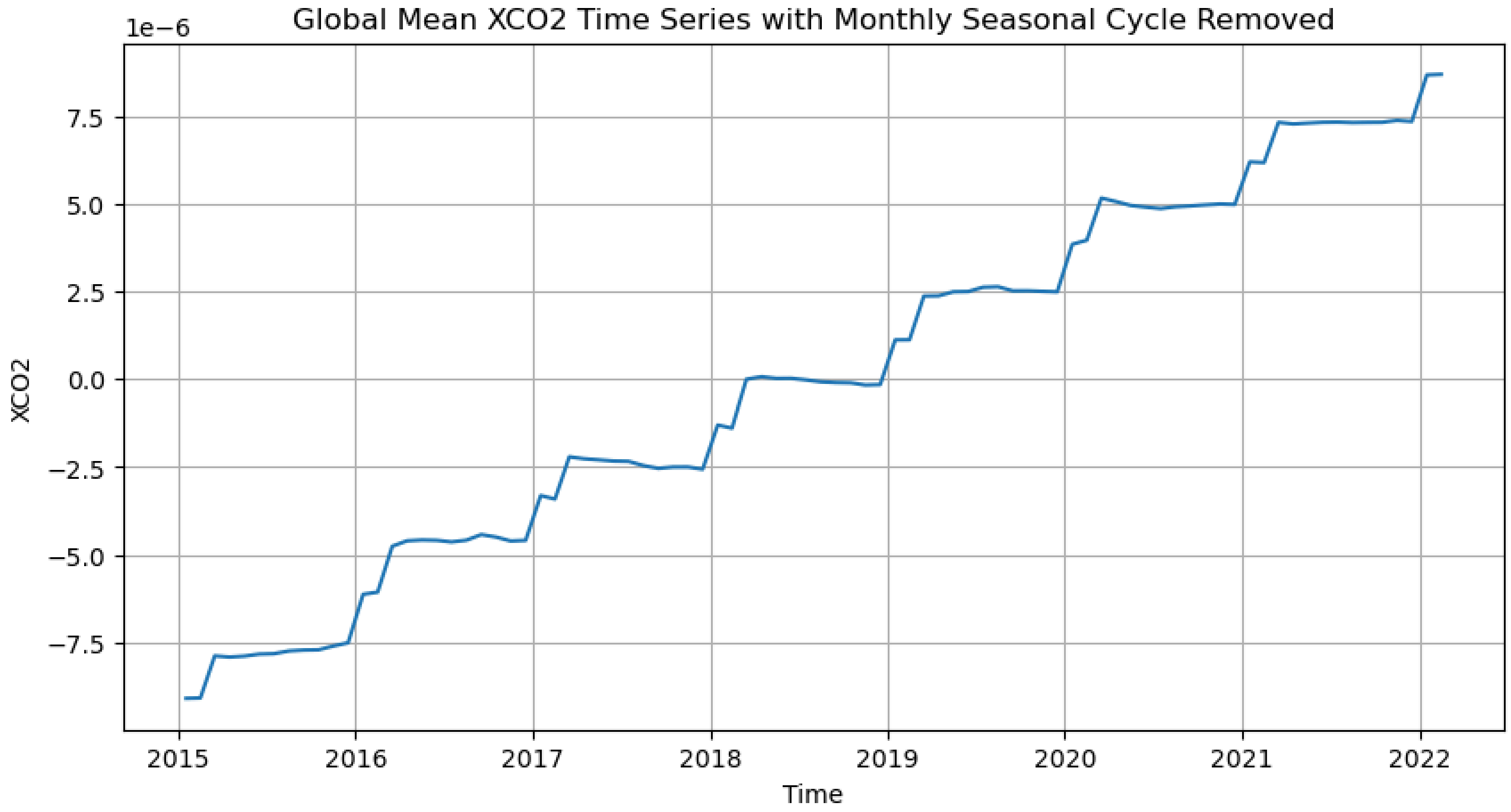
In [23]:
```
#2.2 Visualize the computed Niño 3.4. Your plot should look similar to this one.
sst_anomalies = nino34.groupby('time.month') - sst_climatology
#计算3月滑动平均值
rolling_mean = sst_anomalies.rolling(time=3, center=True).mean()

#计算全区的滑动平均值的平均值
rolling_mean_values = rolling_mean.mean(dim=['lat', 'lon'])

fig, ax = plt.subplots()

#填充曲线到x轴之间区域
```

```python
ax.fill_between(rolling_mean.time.values, rolling_mean_values, where=rolling_mean_values >= 0,
                color='red', interpolate=True, alpha=0.5,label='El Nino Threshold')
ax.fill_between(rolling_mean.time.values, rolling_mean_values, where=rolling_mean_values < 0,
                color='blue', interpolate=True, alpha=0.5, label='La Nina Threshold')

#绘制滑动平均曲线
rolling_mean_values.plot(ax=ax,color='black', label='3mth running mean ')

ax.axhline(0, color='black',linewidth=0.5)

# 添加纵坐标网格线
ax.yaxis.grid(True)
ax.yaxis.grid(which='major', color='black', linestyle='-', linewidth=0.5)
ax.set_yticks([-0.5, 0, 0.5])

# 图例设置在右下角
ax.legend(loc='lower right')
plt.title('SST Anomaly in Nino 3,4 Region (5N-5S,120-170W)')
plt.xlabel('Year')
plt.ylabel('Anomaly in Degrees C')

plt.show()
```



In [3]:
```
#3 Explore a netCDF dataset
#3.1 Plot a time series of a certain variable with monthly seasonal cycle removed.
import xarray as xr
import numpy as np
import matplotlib.pyplot as plt
import glob

# 指定文件夹路径
folder_path = 'D:/GitKraken/ese5023/assignment/assignment3/output_file'

# 获取所有.nc4文件的路径
files = glob.glob(f'{folder_path}/*.nc4')
```

```python
# 使用xarray打开所有文件
ds = xr.open_mfdataset(files, combine='nested', concat_dim='time')

# 选择变量XCO2
variable = ds['XCO2']

# 计算月季节循环（climatology）
monthly_climatology = variable.groupby('time.month').mean('time')

# 去除月季节循环
anomalies = variable.groupby('time.month') - monthly_climatology

# 计算全球平均值
global_mean_anomalies = anomalies.mean(['lat', 'lon'])

# 绘制时间序列图
plt.figure(figsize=(10, 5))
plt.plot(global_mean_anomalies.time, global_mean_anomalies.values)
plt.title('Global Mean XCO2 Time Series with Monthly Seasonal Cycle Removed')
plt.xlabel('Time')
plt.ylabel('XCO2')
plt.grid(True)
plt.show()
```

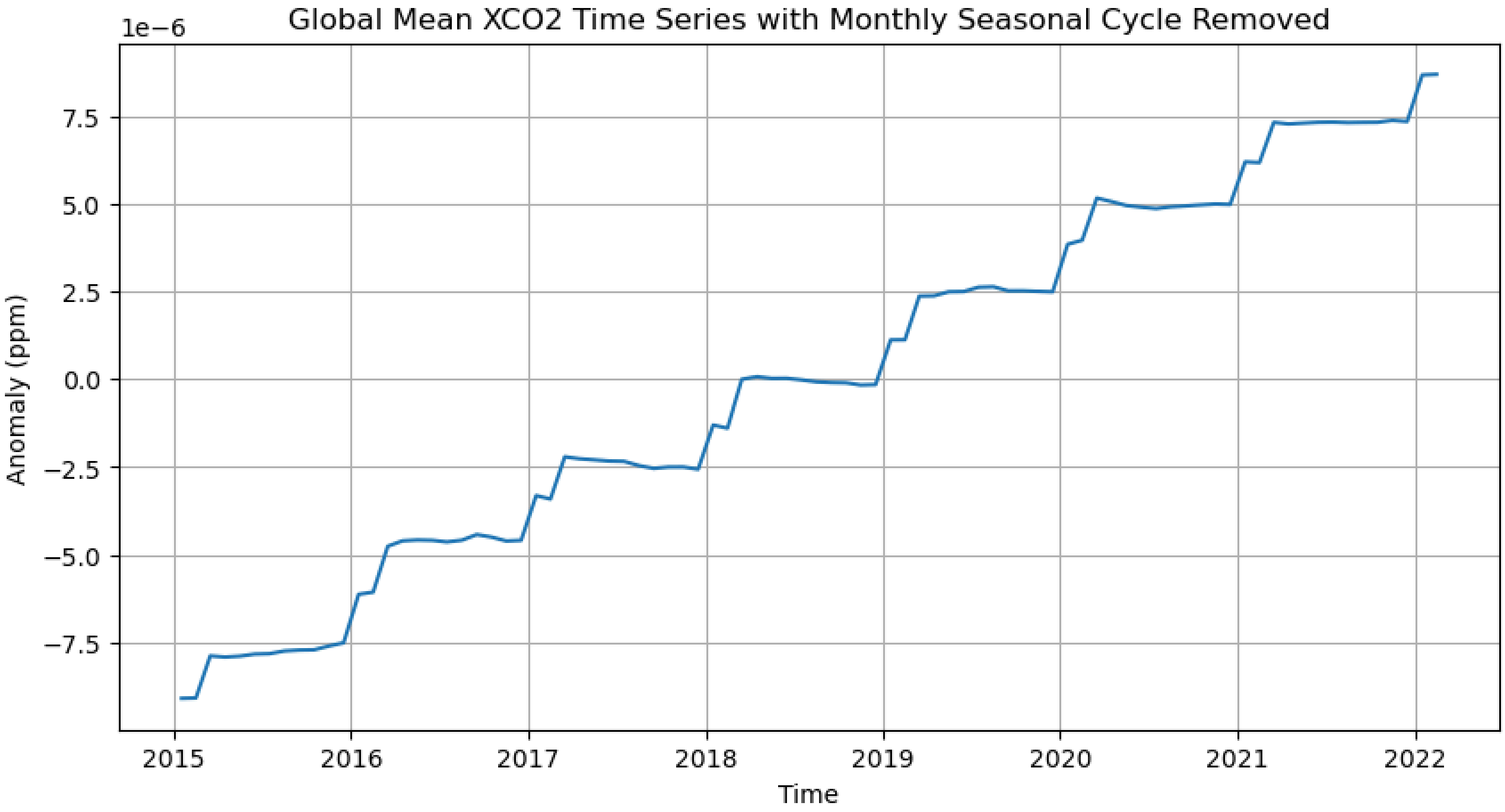


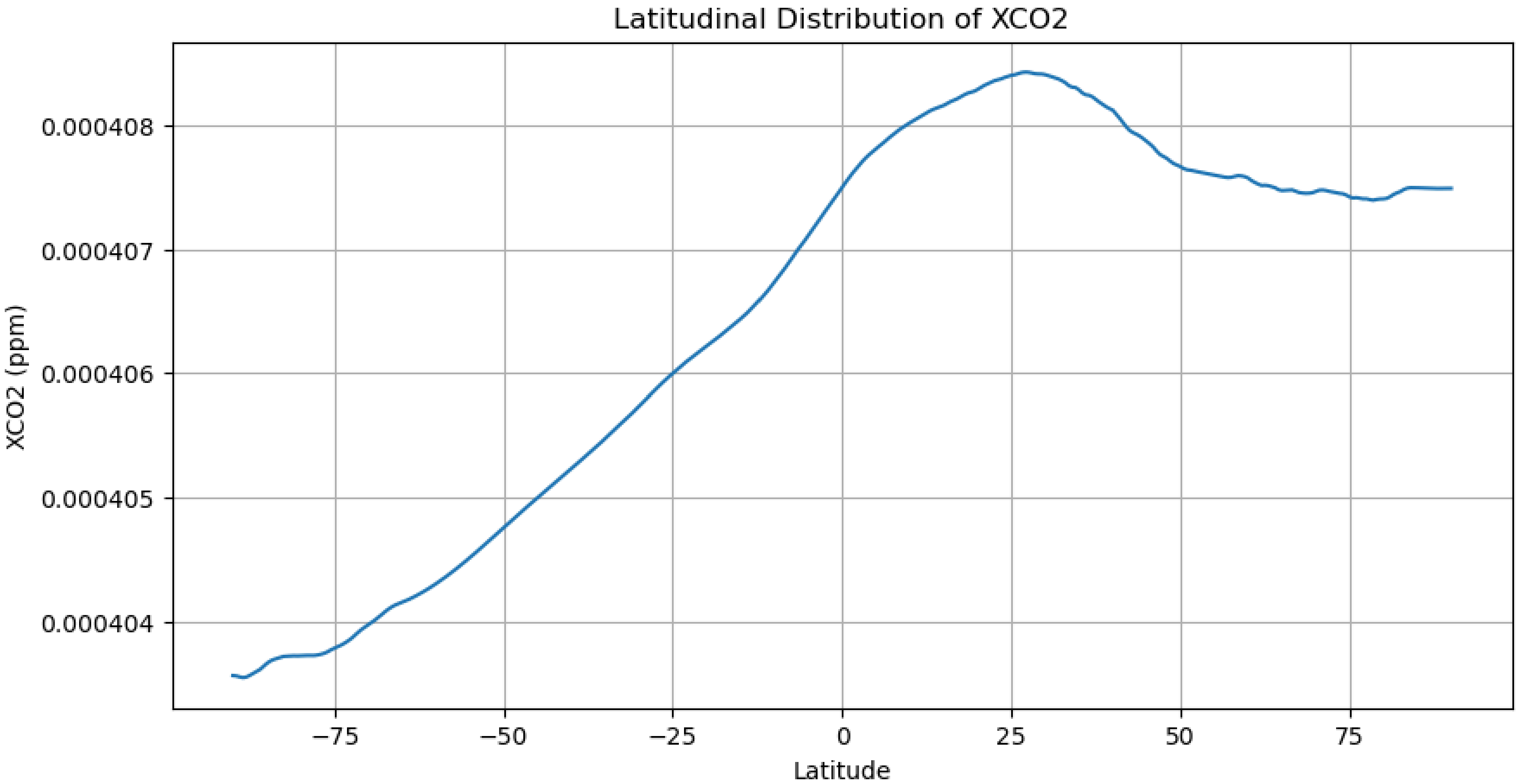
In [5]:

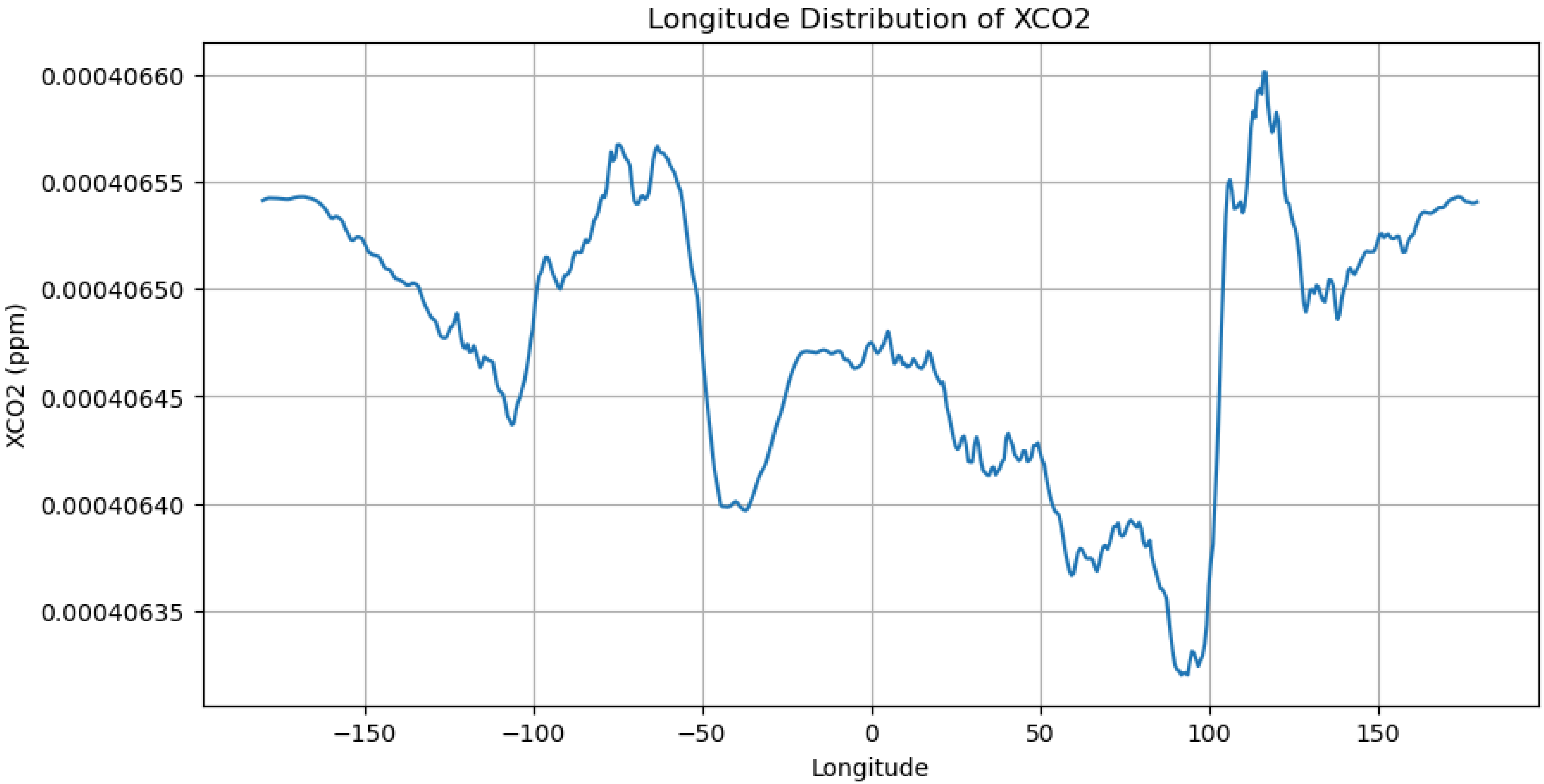
```
#3.2 Make at least 5 different plots using the dataset.
import xarray as xr
import numpy as np
import matplotlib.pyplot as plt
import glob

# Specify the folder path
folder_path = 'D:/GitKraken/ese5023/assignment/assignment3/output_file'

# Get all .nc4 file paths
files = glob.glob(f'{folder_path}/*.nc4')
```

```python
# Use xarray to open all files
ds = xr.open_mfdataset(files, combine='nested', concat_dim='time')

# Select the XCO2 variable
xco2 = ds['XCO2']

# Calculate the monthly climatology
monthly_climatology = xco2.groupby('time.month').mean('time')

# Remove the monthly seasonal cycle
anomalies = xco2.groupby('time.month') - monthly_climatology

# Plot 1: Global Mean Time Series with Monthly Seasonal Cycle Removed
plt.figure(figsize=(10, 5))
plt.plot(anomalies.mean(['lat', 'lon']).time, anomalies.mean(['lat', 'lon']).values)
plt.title('Global Mean XCO2 Time Series with Monthly Seasonal Cycle Removed')
plt.xlabel('Time')
plt.ylabel('Anomaly (ppm)')
plt.grid(True)
plt.show()

# Plot 2: Latitudinal Distribution of XCO2
plt.figure(figsize=(10, 5))
plt.plot(ds['lat'], xco2.mean(['time', 'lon']).values)
plt.title('Latitudinal Distribution of XCO2')
plt.xlabel('Latitude')
plt.ylabel('XCO2 (ppm)')
plt.grid(True)
plt.show()

# Plot 3: Longitude Distribution of XCO2
plt.figure(figsize=(10, 5))
plt.plot(ds['lon'], xco2.mean(['time', 'lat']).values)
plt.title('Longitude Distribution of XCO2')
plt.xlabel('Longitude')
plt.ylabel('XCO2 (ppm)')
plt.grid(True)
plt.show()

# Plot 4: Time Series at Specific Latitude (e.g., Equator)
equator_time_series = xco2.sel(lat=0, method='nearest').mean('lon')
```

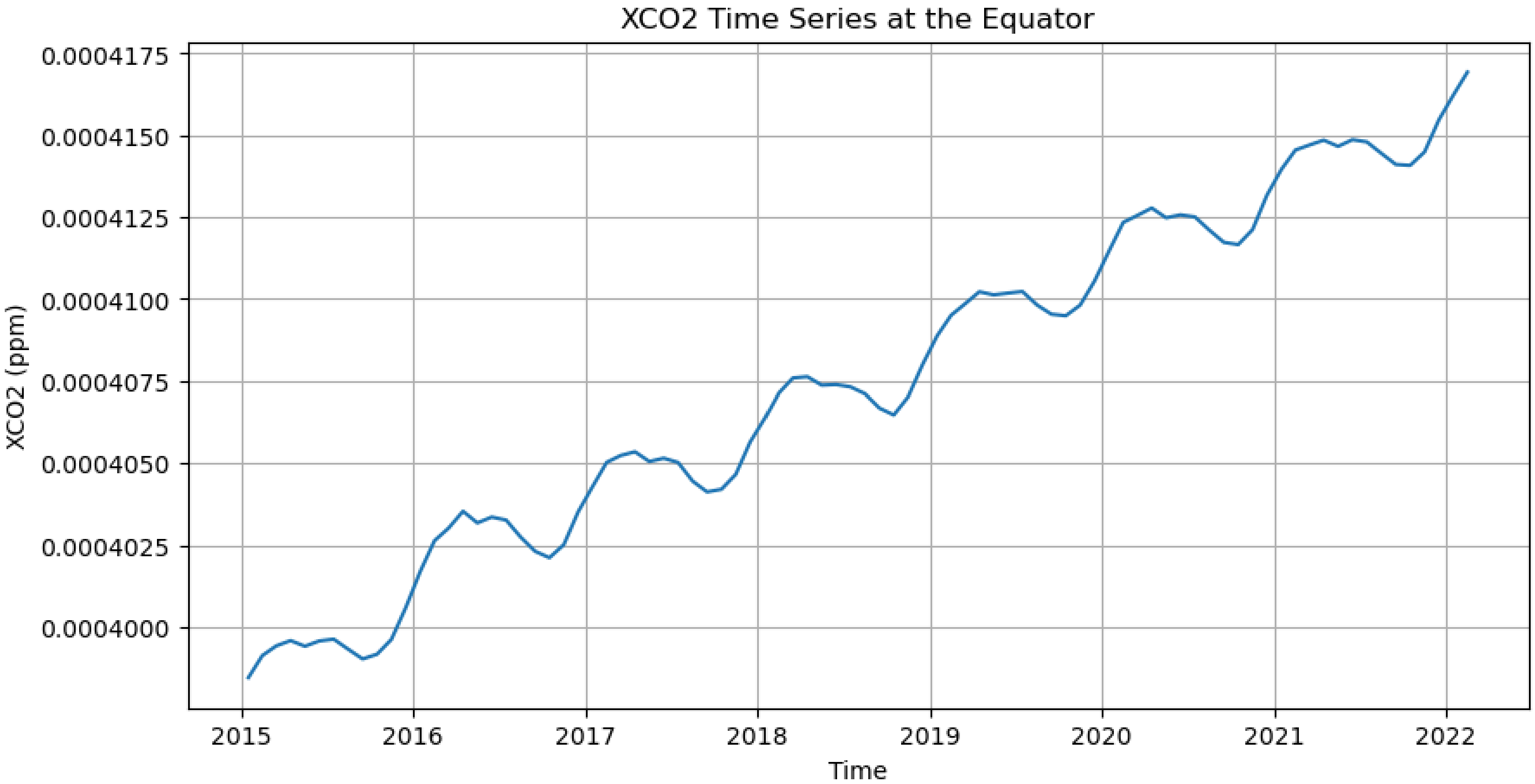
```
plt.figure(figsize=(10, 5))
plt.plot(equator_time_series.time, equator_time_series.values)
plt.title('XCO2 Time Series at the Equator')
plt.xlabel('Time')
plt.ylabel('XCO2 (ppm)')
plt.grid(True)
plt.show()

# Plot 5: 2D plot
# Select a specific time point, e.g., the first time point
selected_time = xco2.isel(time=0)
# Create a 2D plot of global XCO2 distribution
plt.figure(figsize=(12, 6))
plt.imshow(selected_time.values, cmap='coolwarm', extent=[selected_time.lon.min(), selected_time.lon.max(), selected_time.lat.
plt.colorbar(label='XCO2 Concentration (ppm)')
plt.title('Global XCO2 Distribution at Selected Time')
plt.xlabel('Longitude')
plt.ylabel('Latitude')
plt.show()
```

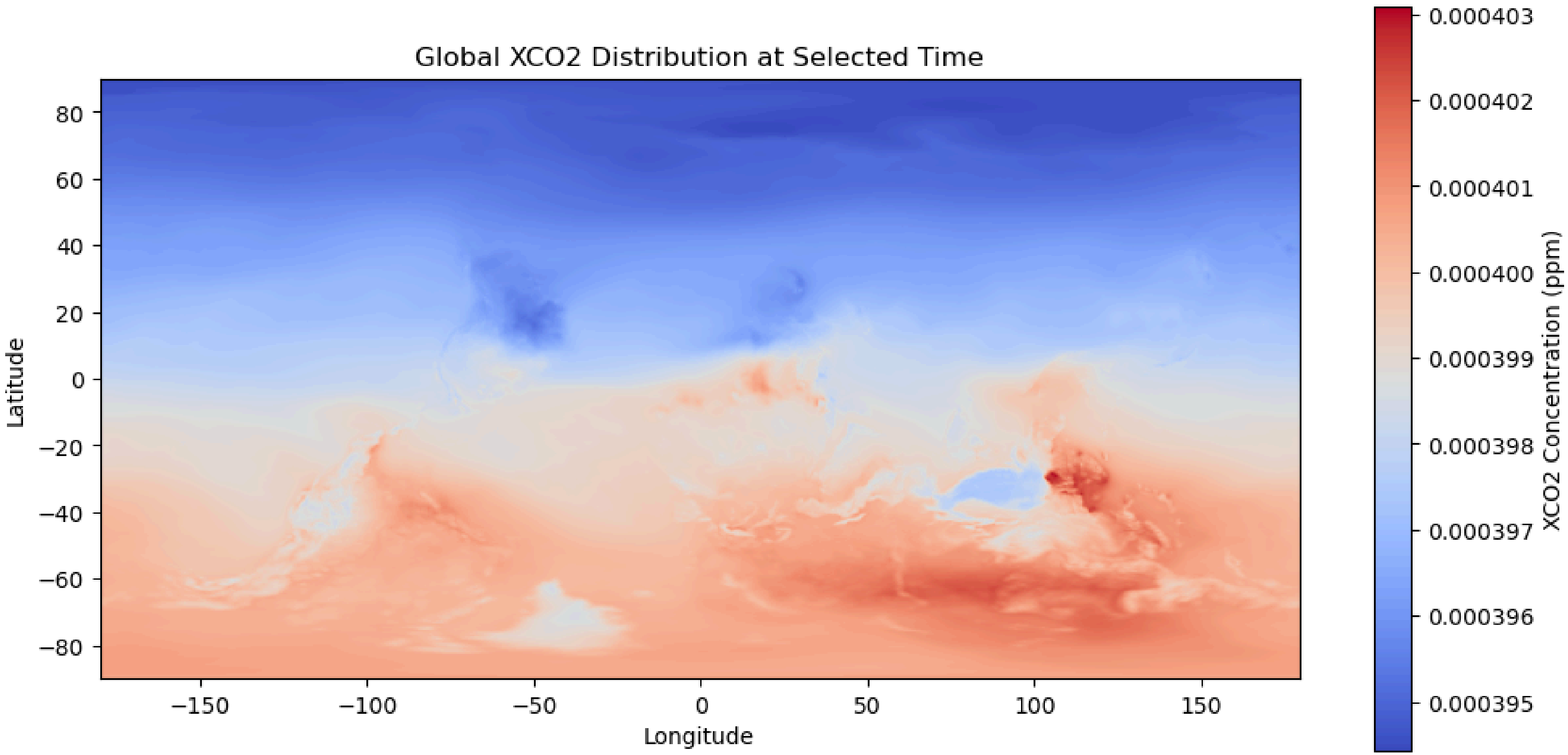

Global Mean XCO2 Time Series with Monthly Seasonal Cycle Removed
1e−6
7.5
5.0
2.5
0.0
−2.5
−5.0
−7.5
Anomaly (ppm)
2015
2016
2017
2018
2019
2020
2021
2022
Time


Latitudinal Distribution of XCO2
0.000408
0.000407
0.000406
0.000405
0.000404
XCO2 (ppm)
−75
−50
−25
0
25
50
75
Latitude



Longitude Distribution of XCO2
0.00040660
0.00040655
0.00040650
0.00040645
0.00040640
0.00040635
XCO2 (ppm)
−150
−100
−50
0
50
100
150
Longitude


XCO2 Time Series at the Equator
0.0004175
0.0004150
0.0004125
0.0004100
0.0004075
0.0004050
0.0004025
0.0004000
XCO2 (ppm)
2015
2016
2017
2018
2019
2020
2021
2022
Time


Global XCO2 Distribution at Selected Time
Latitude
80
60
40
20
0
−20
−40
−60
−80
−150
−100
−50
0
50
100
150
Longitude
0.000403
0.000402
0.000401
0.000400
0.000399
0.000398
0.000397
0.000396
0.000395
XCO2 Concentration (ppm)

In [ ]: