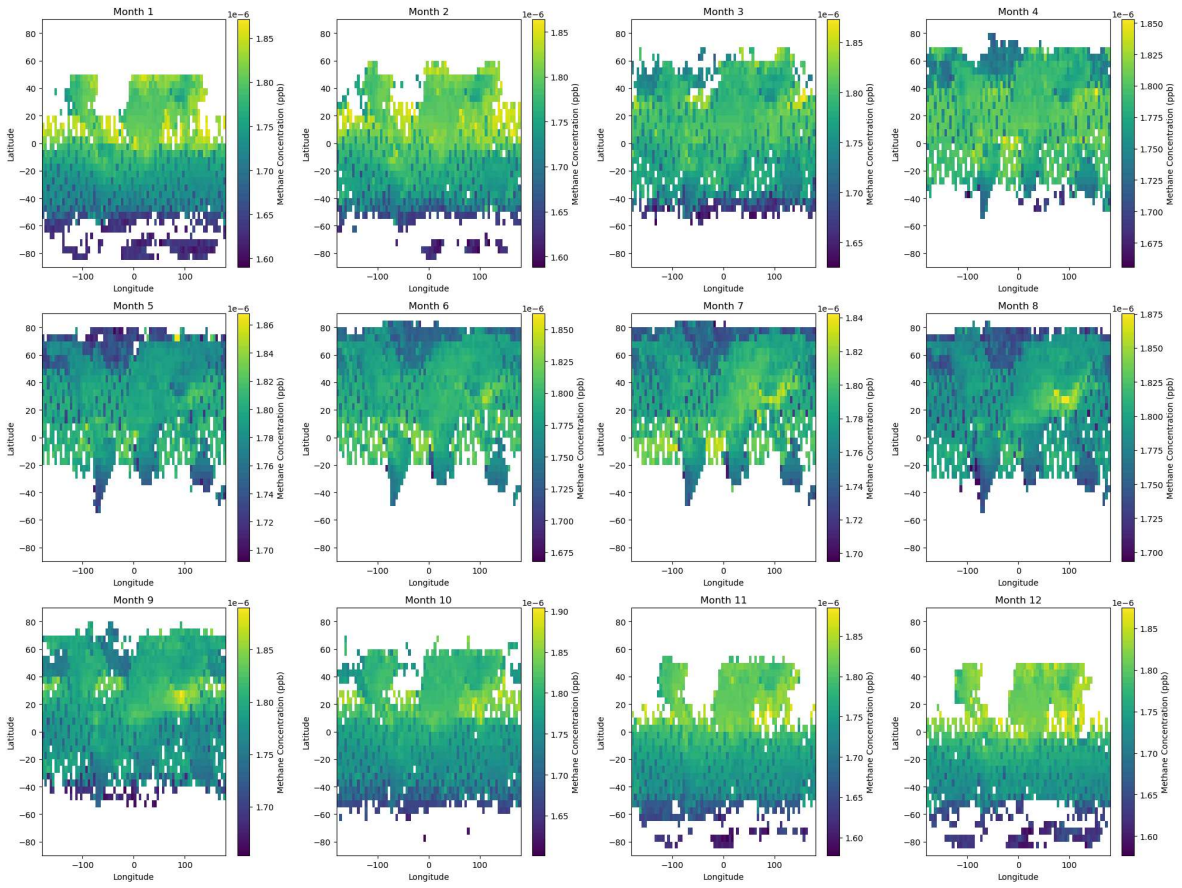
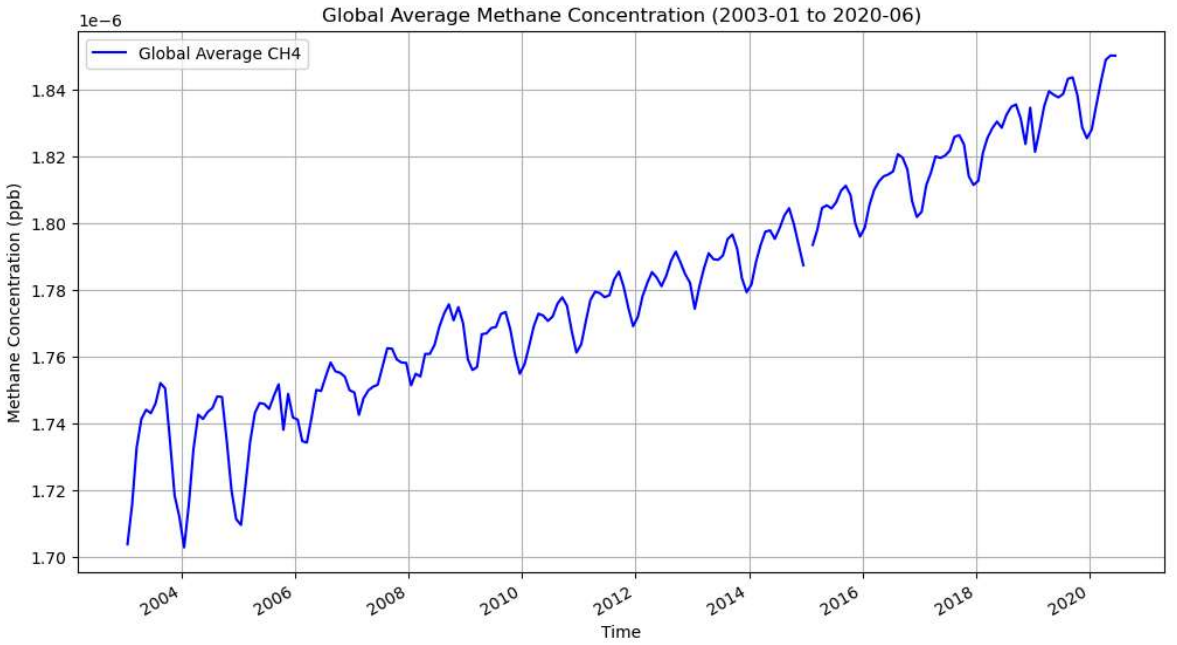
1. Global methane levels from 2002

In [23]:
```
import xarray as xr
import matplotlib.pyplot as plt

# 读取netCDF文件
ds = xr.open_dataset('200301_202006-C3S-L3_GHG-PRODUCTS-OBS4MIPS-MERGED-v4.3.nc'

# 1.1
# 提取甲烷浓度数据
xch4 = ds.xch4

# 计算每个月的平均值
monthly_climatology = xch4.groupby('time.month').mean(dim='time')

# 绘制每个月的甲烷气候学
fig, axs = plt.subplots(3, 4, figsize=(20, 15))
for i in range(12):
    ax = axs[i // 4, i % 4]
    monthly_climatology[i].plot(ax=ax, cmap='viridis', cbar_kwargs={'label': 'Me
    ax.set_title(f'Month {i + 1}')
    ax.set_xlabel('Longitude')
    ax.set_ylabel('Latitude')

plt.tight_layout()
plt.show()
```

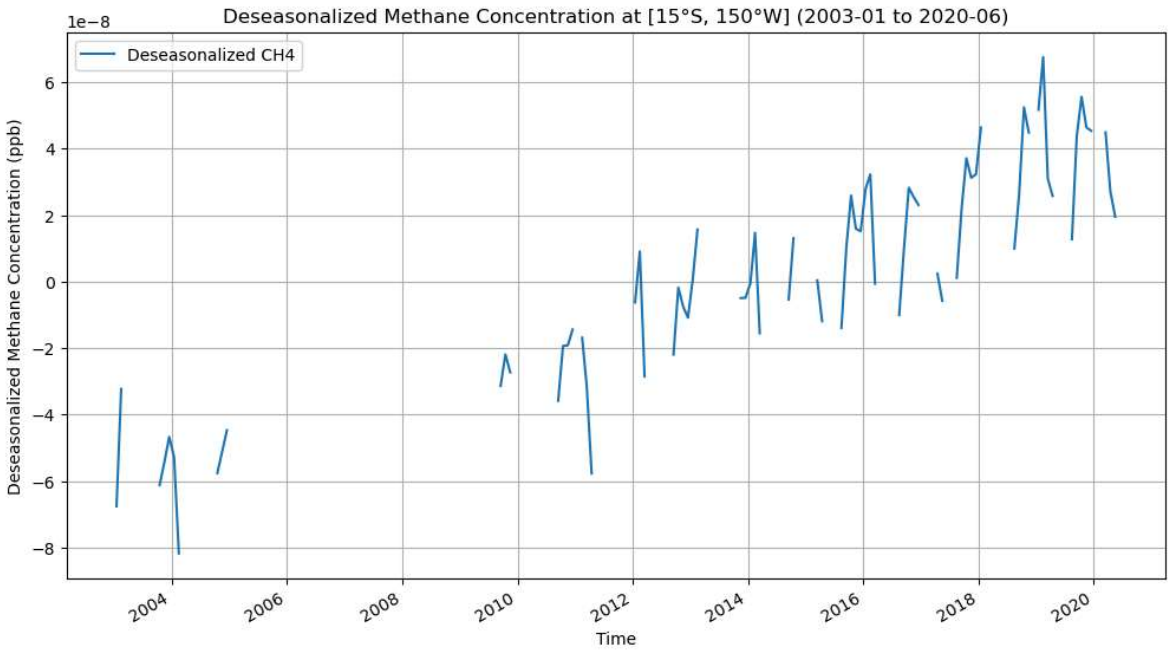


In [25]:
```
# 1.2
#计算全球平均甲烷浓度
global_mean_xch4 = xch4.mean(dim=('lat', 'lon'))
```

```
# 绘制时间序列
plt.figure(figsize=(12, 6))
global_mean_xch4.plot(label='Global Average CH4', color='blue')
plt.title('Global Average Methane Concentration (2003-01 to 2020-06)')
plt.xlabel('Time')
plt.ylabel('Methane Concentration (ppb)')
plt.grid()
plt.legend()
plt.show()
```



In [27]:
```
# 1.3
# 提取特定点的甲烷浓度
point_xch4 = xch4.sel(lat=-15, lon=150, method='nearest')

# 计算去季节化
monthly_means = point_xch4.groupby('time.month').mean(dim='time')
deseasonalized = point_xch4.groupby('time.month') - monthly_means

# 判别是否有有效数据
if deseasonalized.count() > 0:
    plt.figure(figsize=(12, 6))
    deseasonalized.plot(label='Deseasonalized CH4')
    plt.title('Deseasonalized Methane Concentration at [15°S, 150°W] (2003-01 to
    plt.xlabel('Time')
    plt.ylabel('Deseasonalized Methane Concentration (ppb)')
    plt.grid()
    plt.legend()
    plt.show()
else:
    print("去季节化结果没有有效数据。")
```



2. Niño 3.4 index

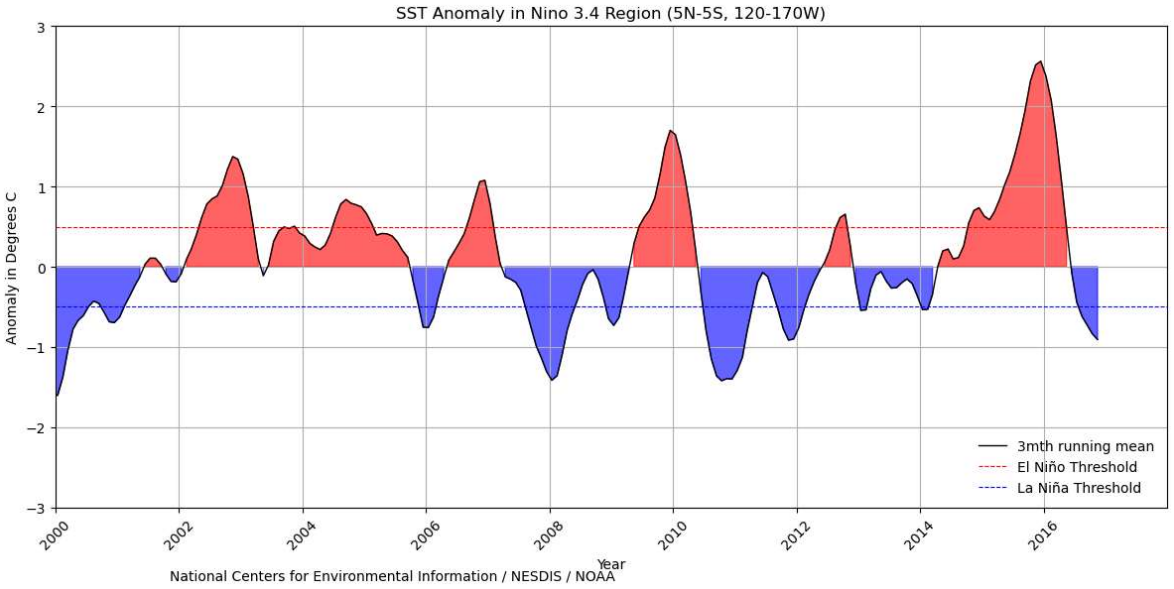
In [29]:
```
import xarray as xr
import numpy as np

# 读取 netCDF 文件
ds = xr.open_dataset('NOAA_NCDC_ERSST_v3b_SST.nc')

# 2.1
# 选择 Niño 3.4 区域的 SST 数据
sst_nino34 = ds.sst.sel(lat=slice(-5, 5), lon=slice(190, 240))

# 计算每个月的气候平均值
monthly_climatology = sst_nino34.groupby('time.month').mean('time')

# 计算 SST 异常值
sst_anomalies = sst_nino34.groupby('time.month') - monthly_climatology

# 输出异常值
print(sst_anomalies)
```

```
<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 190.0 192.0 194.0 196.0 ... 234.0 236.0 238.0 240.0
  * time     (time) datetime64[ns] 1960-01-15 1960-02-15 ... 2016-12-15
    month    (time) int64 1 2 3 4 5 6 7 8 9 10 11 ... 2 3 4 5 6 7 8 9 10 11 12
```

In [31]:

```python
# 2.2
# 计算 3 个月的滑动平均
sst_anomalies_smooth = sst_anomalies.rolling(time=3, center=True).mean()

# 计算平均值以获得一维数组
sst_anomalies_smooth_mean = sst_anomalies_smooth.mean(dim=['lat', 'lon'])

# 将 xarray 数组转换为 NumPy 数组以便绘图
time_vals = sst_anomalies_smooth_mean['time'].values
anomalies_vals = sst_anomalies_smooth_mean.values

# 创建图形
```

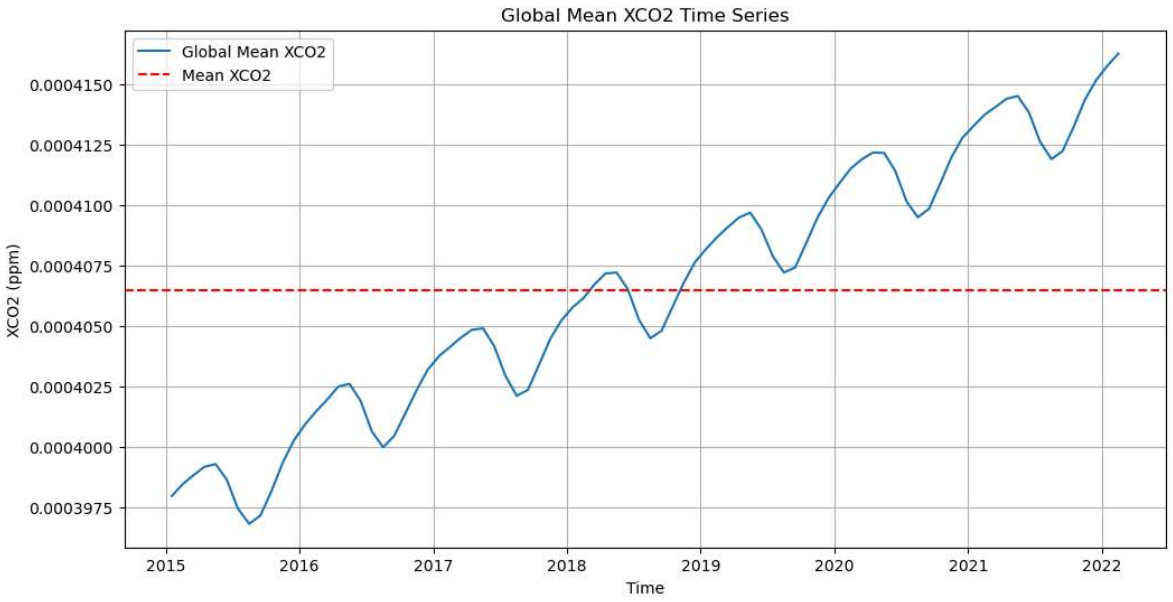
```
plt.figure(figsize=(12, 6))

# 绘制异常值图
plt.plot(time_vals, anomalies_vals, color='black', linewidth=1, label='3mth runn

# 填充 El Niño 区域
plt.fill_between(time_vals, anomalies_vals, where=(anomalies_vals > 0),
                 color='red', alpha=0.6)
# 填充 La Niña 区域
plt.fill_between(time_vals, anomalies_vals, where=(anomalies_vals < 0),
                 color='blue', alpha=0.6)

# 添加阈值线
plt.axhline(0.5, color='red', linewidth=0.8, linestyle='--', label='El Niño Thre
plt.axhline(-0.5, color='blue', linewidth=0.8, linestyle='--', label='La Niña Th

# 设置横纵轴标签和范围
plt.title('SST Anomaly in Nino 3.4 Region (5N-5S, 120-170W)')
plt.xlabel('Year')
plt.ylabel('Anomaly in Degrees C')
plt.xlim([np.datetime64('2000-01-01'), np.datetime64('2017-12-31')])
plt.ylim([-3.0, 3.0])

# 图例设置
plt.legend(loc='lower right', frameon=False)

# 添加网格线和格式
plt.grid(True)
plt.xticks(rotation=45)

# 添加来源信息
plt.figtext(0.15, 0.01, 'National Centers for Environmental Information / NESDIS

# 显示图形
plt.tight_layout()
plt.show()
```



3. Explore a netCDF dataset

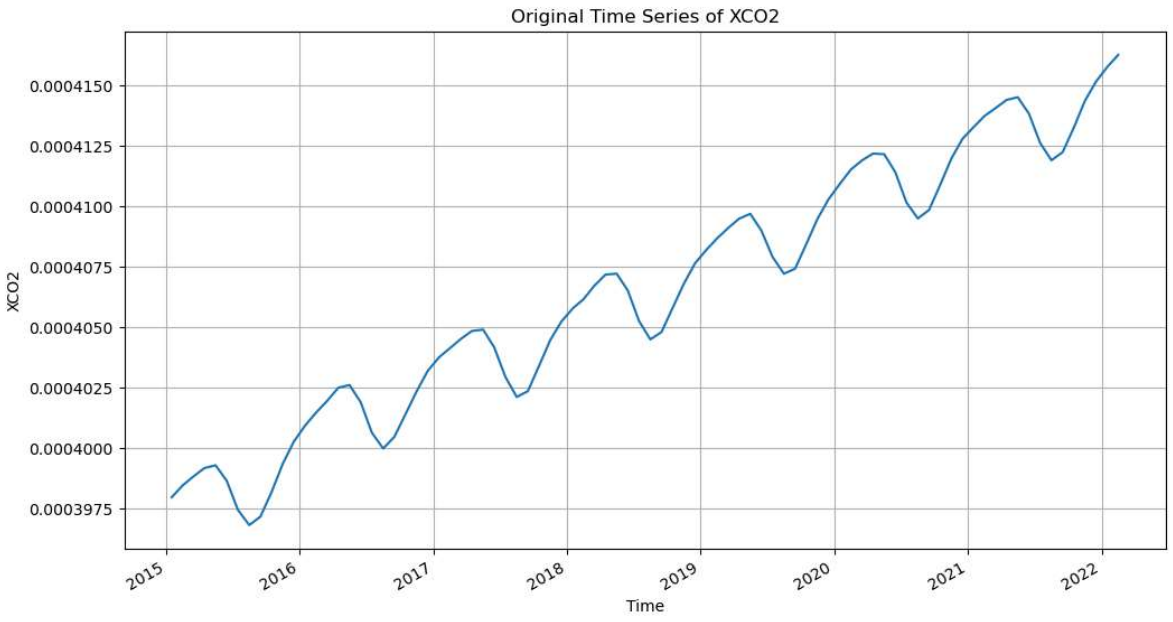
In [16]:
```
import xarray as xr
import numpy as np
import matplotlib.pyplot as plt
import glob

# 指定文件夹路径
folder_path = 'D:\ESE5023\output_file'

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

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

# 3.1
# 选择变量 XCO2
data = ds['XCO2']

# 计算全球均值
global_mean = data.mean(dim=('lat', 'lon'))

# 绘制时间序列图，使用线性格式
plt.figure(figsize=(12, 6))
plt.plot(global_mean['time'], global_mean, color='tab:blue', label='Global Mean
plt.title('Global Mean XCO2 Time Series')
plt.xlabel('Time')
plt.ylabel('XCO2 (ppm)')  # 单位可以根据您的数据调整
plt.axhline(global_mean.mean(), color='red', linestyle='--', label='Mean XCO2')
plt.legend()
plt.grid()
plt.show()
```

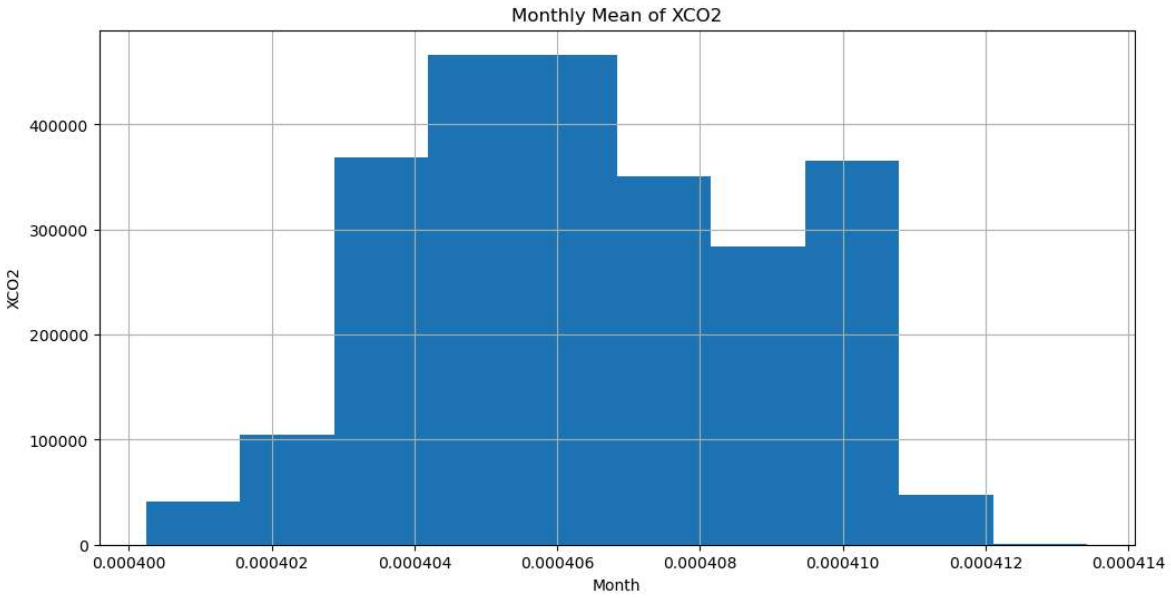
```
<>:7: SyntaxWarning: invalid escape sequence '\E'
<>:7: SyntaxWarning: invalid escape sequence '\E'
C:\Users\86133\AppData\Local\Temp\ipykernel_1380\3852068932.py:7: SyntaxWarning:
invalid escape sequence '\E'
  folder_path = 'D:\ESE5023\output_file'
```

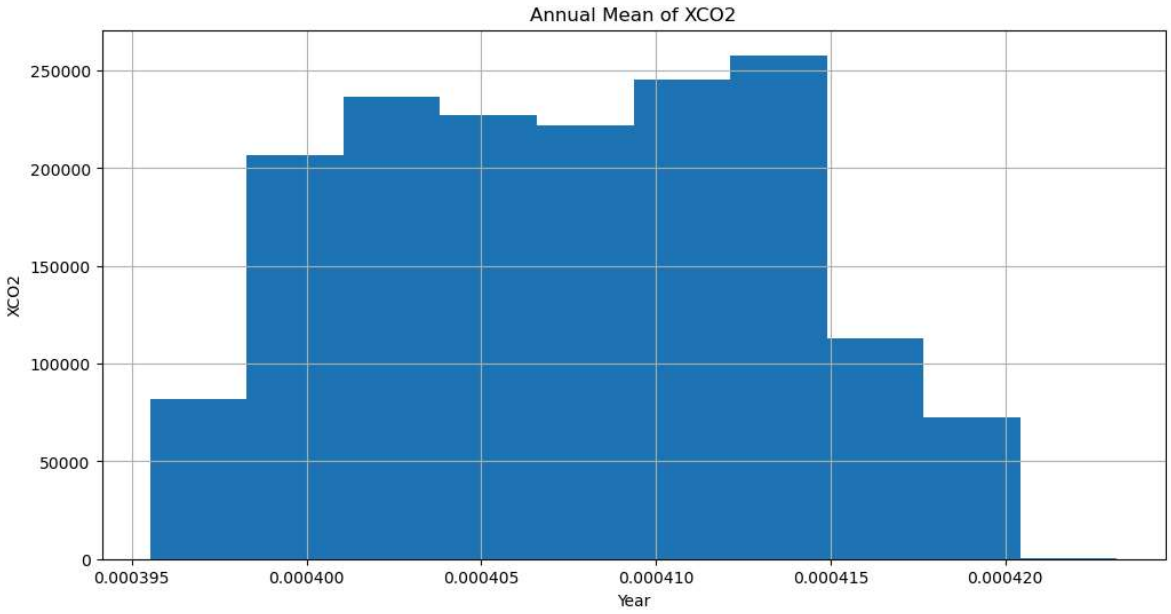


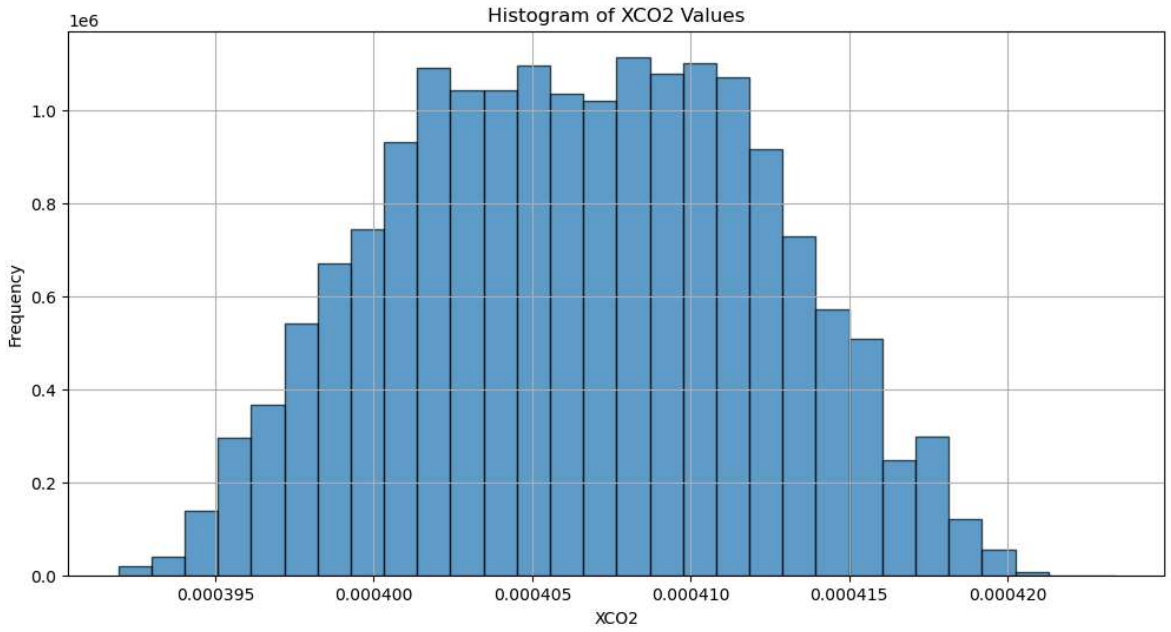
In [19]:
```
# 3.2
# 1. 原始时间序列图
plt.figure(figsize=(12, 6))
```

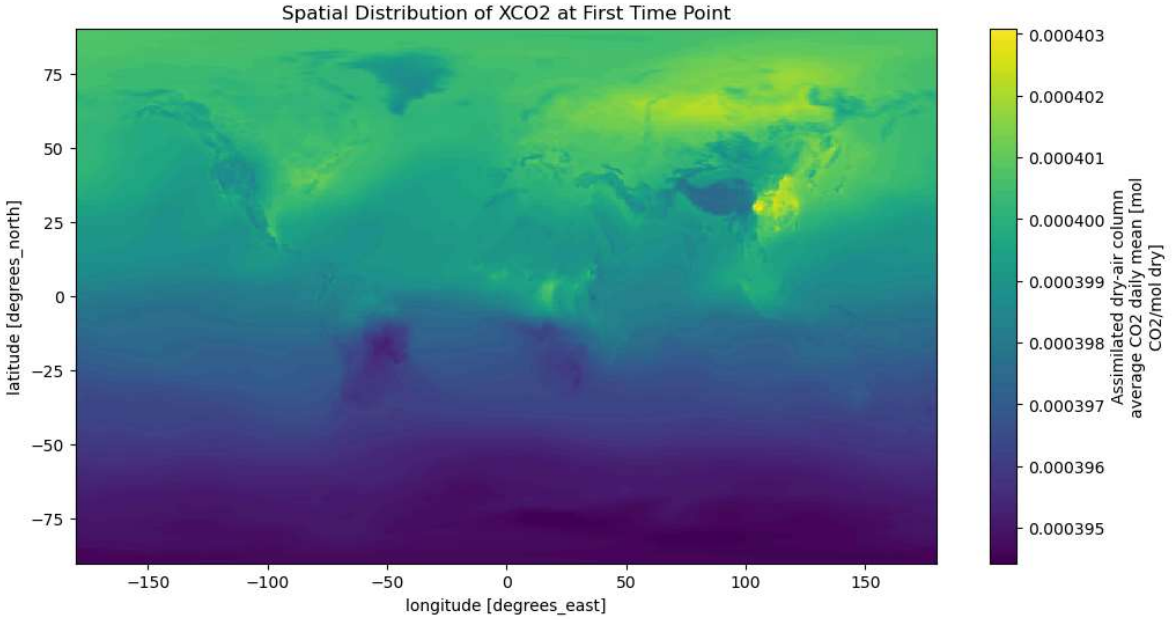
```
data.mean(dim=('lat', 'lon')).plot()
plt.title('Original Time Series of XCO2')
plt.xlabel('Time')
plt.ylabel('XCO2')
plt.grid()
plt.show()

# 2. 月均值图
monthly_mean = data.groupby('time.month').mean('time')
plt.figure(figsize=(12, 6))
monthly_mean.plot()
plt.title('Monthly Mean of XCO2')
plt.xlabel('Month')
plt.ylabel('XCO2')
plt.grid()
plt.show()

# 3. 年均值图
annual_mean = data.groupby('time.year').mean('time')
plt.figure(figsize=(12, 6))
annual_mean.plot()
plt.title('Annual Mean of XCO2')
plt.xlabel('Year')
plt.ylabel('XCO2')
plt.grid()
plt.show()

# 4. 时间序列的直方图
plt.figure(figsize=(12, 6))
plt.hist(data.values.flatten(), bins=30, edgecolor='k', alpha=0.7)
plt.title('Histogram of XCO2 Values')
plt.xlabel('XCO2')
plt.ylabel('Frequency')
plt.grid()
plt.show()

# 5. XCO2的空间分布图
plt.figure(figsize=(12, 6))
data.isel(time=0).plot(cmap='viridis')
plt.title('Spatial Distribution of XCO2 at First Time Point')
plt.show()
```




Monthly Mean of XCO2
XCO2
Month
0
100000
200000
300000
400000
0.000400
0.000402
0.000404
0.000406
0.000408
0.000410
0.000412
0.000414


Annual Mean of XCO2
XCO2
Year
0
50000
100000
150000
200000
250000
0.000395
0.000400
0.000405
0.000410
0.000415
0.000420


Histogram of XCO2 Values
1e6
Frequency
XCO2
0.0
0.2
0.4
0.6
0.8
1.0
0.000395
0.000400
0.000405
0.000410
0.000415
0.000420


Spatial Distribution of XCO2 at First Time Point
latitude [degrees_north]
75
50
25
0
−25
−50
−75
−150
−100
−50
0
50
100
150
longitude [degrees_east]
0.000403
0.000402
0.000401
0.000400
0.000399
0.000398
0.000397
0.000396
0.000395
Assimilated dry-air column average CO2 daily mean [mol CO2/mol dry]