在 [41]…

```
# Assignment 03 by Yang Yi 12432892

import numpy as np
import pandas as pd
import xarray as xr
from matplotlib import pyplot as plt
%matplotlib inline

# 1.Global methane levels from 2002
import netCDF4 as nc
import numpy as np
import matplotlib.pyplot as plt
import matplotlib as mpl
import matplotlib.gridspec as gridspec
```

在 [43]…

```
# 读取文件
ds=xr.open_dataset("200301_202006-C3S-L3_GHG-PRODUCTS-OBS4MIPS-MERGED-v4.3.nc",engine="netcdf4")
ds
```

出[43]： xarray 的数据

► 尺寸： (**时间**：210, BNDS：2, **纬度**： 36, **纬度**： 72, 压力： 10)

▼坐标：

时间	(时间)	日期时间 64[ns]	2003-01-16T12：00：00 ...2...
纬度	(纬度)	浮动64	-87.5 -82.5 -77.5 ...82.5 87.5
离子	(隆)	浮动64	-177.5 -172.5 ...172.5 177.5

▼数据变量：

time_bnds	(时代、BNDS)	日期时间 64[ns]	...
lat_bnds	(纬度、BNDS)	浮动64	...
lon_bnds	(LON，BNDS)	浮动64	...
前	(压力)	浮动64	...
pre_bnds	(压力，BNDS)	浮动64	...
land_fraction	(纬度、纬度)	浮动64	...
XCH4	(时间、纬度、经度)	浮点数32	...
xch4_nobs	(时间、纬度、经度)	浮动64	...
xch4_stderr	(时间、纬度、经度)	浮点数32	...
xch4_stddev	(时间、纬度、经度)	浮点数32	...
column_averag...	(时间、压力、纬度、经度)	浮点数32	...
vmr_profile_ch...	(时间、压力、纬度、经度)	浮点数32	...

► 指标： (3)

► 属性： (28)

在 [45]...

```
xch4 = ds.variables['xch4'][:]
ds['xch4']
```

出局[45]…

xarray 的
DataArray'xch4'
(**时间**：210, **纬度**： 36, **纬度**： 72)

[544320 values with dtype=float32]

▼坐标：

时间	(时间)	日期时间 64[ns]	2003-01-16T12：00：00 ...2020-06-16
纬度	(纬度)	浮动64	-87.5 -82.5 -77.5 ...82.5 87.5
离子	(隆)	浮动64	-177.5 -172.5 ...172.5 177.5

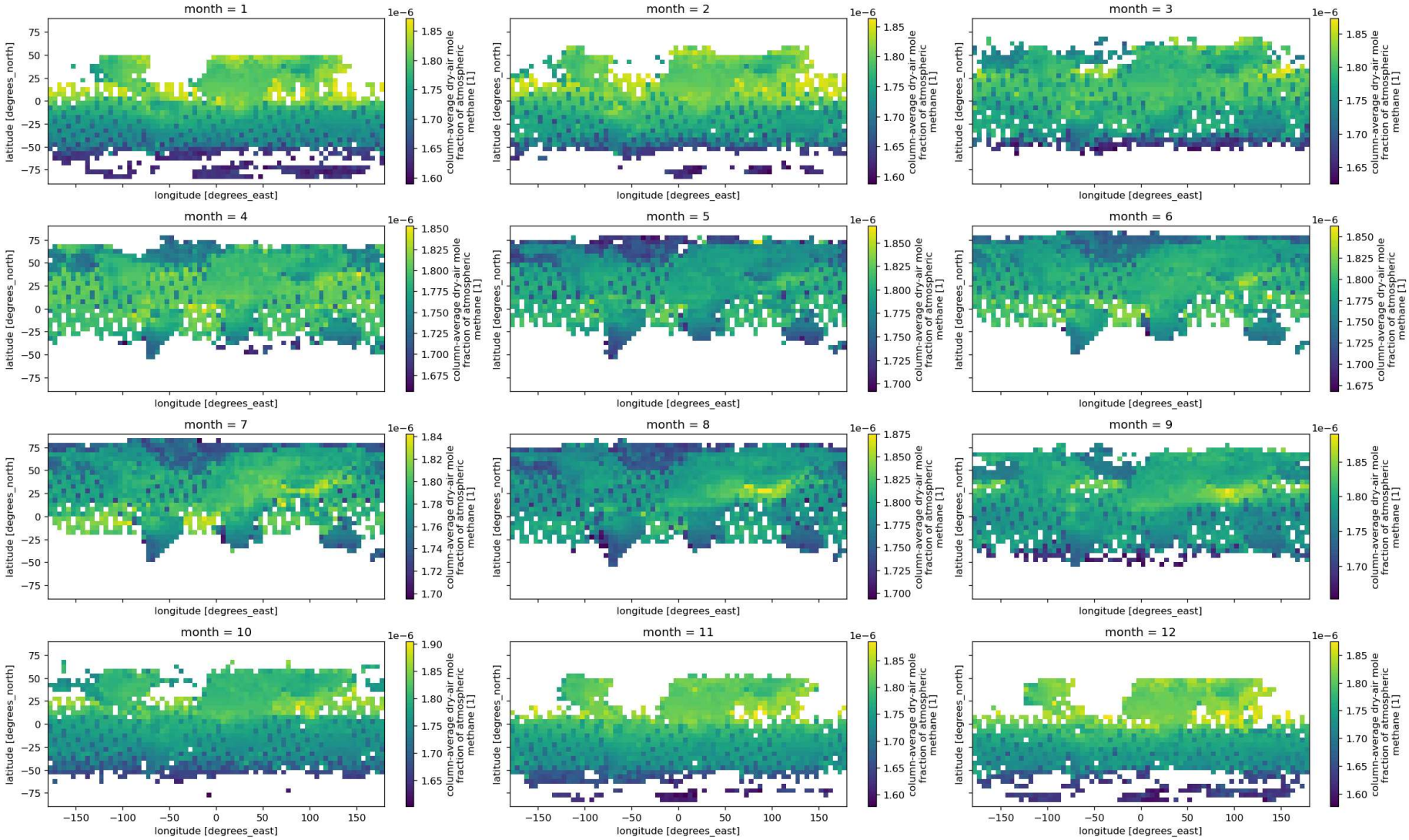
►指标： (3)

▼属性：

standard_name...	dry_atmosphere_mole_fraction_of_methane
long_name：	大气中甲烷的柱平均干空气摩尔分数
单位:	1
cell_methods：	时间：平均值
fill_value：	1E+20
评论:	卫星检索的大气甲烷 （XCH4） 的柱平均干空气摩尔分数

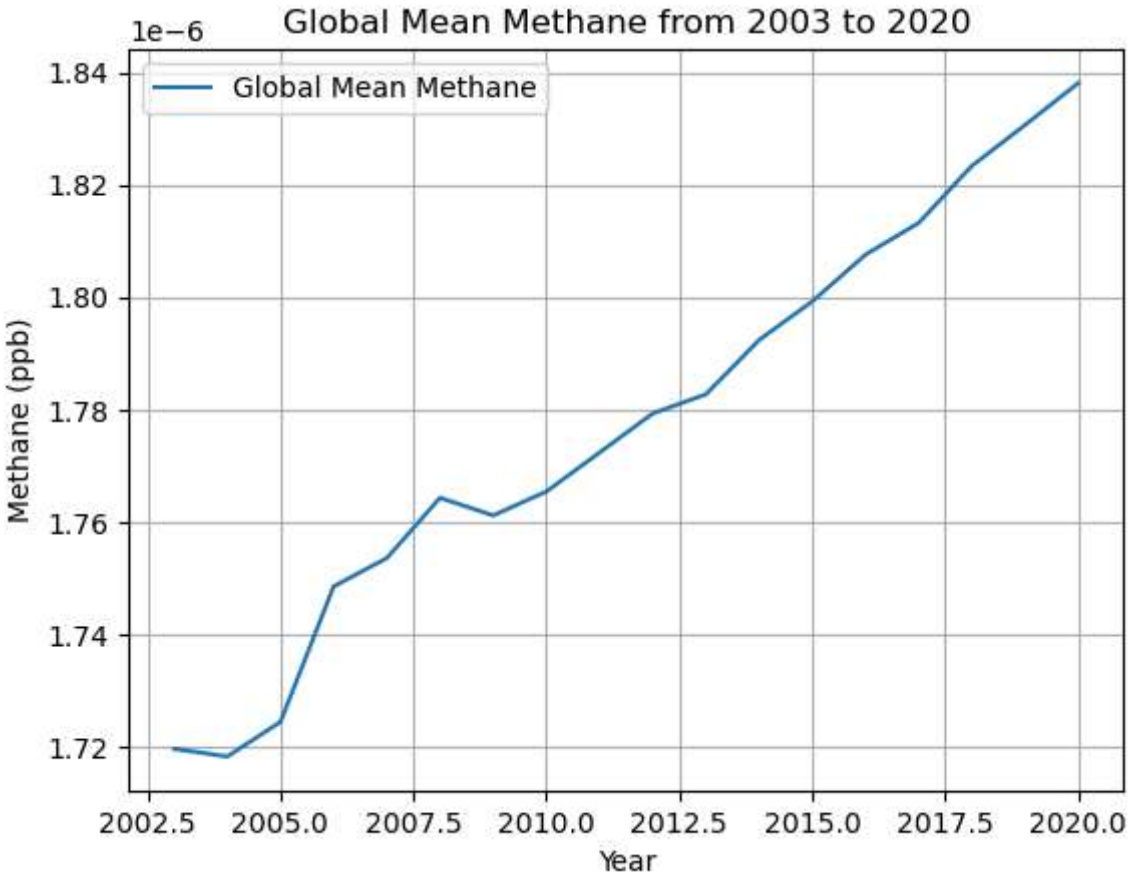
在 [47]…

```
# 1.1 计算每月甲烷气候学并绘制结果
# 计算每月气候学
monthly_climatology =ds.xch4.groupby('time.month').mean()
# 创建12个月的表格
fig,axes=plt.subplots(4,3,figsize=(20,12),sharex=True,sharey=True,dpi=120)
# 拉成一维数组
axes=axes.ravel()
for i in range(12):
    axes[i]=plt.subplot(4,3,i+1)
    monthly_climatology[i,:,:].plot()
    plt.tight_layout()  # 调整布局
```



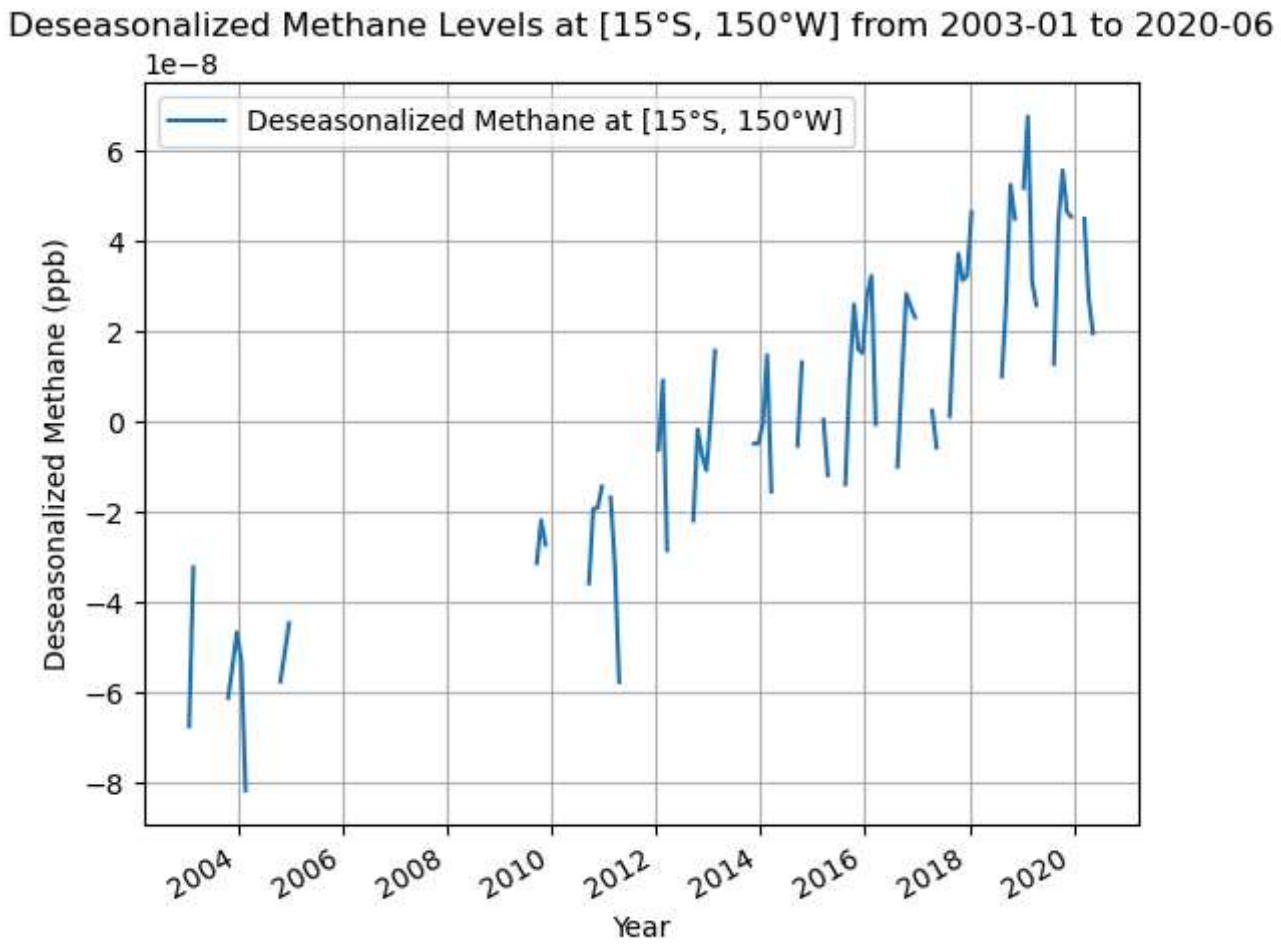
In [48]:
```
# 1.2 绘制2003年1月至2020年6月全球平均甲烷时间序列
xch4 = ds['xch4']
# 按年份分组并计算每年的平均值
xch4_year = xch4.groupby('time.year').mean()
# 计算全球平均
xch4_global_mean = xch4_year.mean(dim=['lon', 'lat'])
# 绘制时间序列
```

```
xch4_global_mean.plot(label='Global Mean Methane')
plt.title('Global Mean Methane from 2003 to 2020')
plt.xlabel('Year')
plt.ylabel('Methane (ppb)')
plt.legend()
plt.grid(True)
plt.show()

# 全球甲烷含量在逐步增加，并且含量增高趋势逐渐更加明显
```



In [49]:
```
# 1.3 绘制2003年1月至2020年6月[15°S, 150°W]点去季节化甲烷水平时间序列
# 在南纬15度，西经150度处去季节性甲烷变化总体上在逐年增高
lat_point = -15
```

```
lon_point = 150
# 提取特定点数据
methane_at_point = ds['xch4'].sel(lat=lat_point, lon=lon_point, method='nearest')
# 计算季节平均值
seasonal_mean = methane_at_point.groupby('time.month').mean()
# 去季节化
deseasonalized = methane_at_point.groupby('time.month') - seasonal_mean
# 绘制去季节化后的时间序列
deseasonalized.plot(label='Deseasonalized Methane at [15°S, 150°W]')
plt.title('Deseasonalized Methane Levels at [15°S, 150°W] from 2003-01 to 2020-06')
plt.xlabel('Year')
plt.ylabel('Deseasonalized Methane (ppb)')
plt.legend()
plt.grid(True)
plt.show()
```



In [50]:
```
# 2.Niño 3.4 index
# 本题我求助了我的师姐龙师倩
SST=xr.open_dataset("NOAA_NCDC_ERSST_v3b_SST.nc",engine='netcdf4')
SST
```

Out[50]: xarray.Dataset

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

▼ Coordinates:

lat	(lat)	float32	-88.0 -86.0 -84.0 ... 86.0 88.0	
lon	(lon)	float32	0.0 2.0 4.0 ... 354.0 356.0 358.0	
time	(time)	datetime64[ns]	1960-01-15 ... 2016-12-15	

▼ Data variables:

sst	(time, lat, lon)	float32	...

► Indexes: (3)

▼ Attributes:

Conventions :	IRIDL
source :	https://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCDC/.ERSST/.version3b/.sst/
history :	extracted and cleaned by Ryan Abernathey for Research Computing in Earth Science

In [51]:
```
SST['sst']
```

Out[51]: xarray.DataArray

'sst'

(**time**: 684, **lat**: 89, **lon**: 180)

[10957680 values with dtype=float32]

▼ Coordinates:

lat	(lat)	float32	-88.0 -86.0 -84.0 ... 86.0 88.0
lon	(lon)	float32	0.0 2.0 4.0 ... 354.0 356.0 358.0
time	(time)	datetime64[ns]	1960-01-15 ... 2016-12-15

► Indexes: (3)

▼ Attributes:

pointwidth :	1.0
valid_min :	-3.0
valid_max :	45.0
units :	degree_Celsius
long_name :	Extended reconstructed sea surface temperature
standard_name :	sea_surface_temperature
iridl:hasSemant...	iridl:SeaSurfaceTemperature

In [52]:
```
#2.1 计算Niño 3.4区域SST的月度气候学和异常值
group_data = SST.sst.sel(lon=slice(120,170),lat=slice(-5,5)).groupby('time.month')
sst_dif = group_data-group_data.mean(dim='time')
# 计算得到异常值
anomalies = sst_dif.resample(time="3M").mean(dim="time")
anomalies
```

```
D:\python111\Lib\site-packages\xarray\core\groupby.py:508: FutureWarning: 'M' is deprecated and will be removed in a future ver
sion, please use 'ME' instead.
  index_grouper = pd.Grouper(
```

Out[52]: xarray.DataArray

'sst'

(**time**: 229, **lat**: 5, **lon**: 26)

```
array([[[-0.4533596 , -0.43008804, -0.3652172 , ..., -0.5904255 ,
         -0.51613617, -0.5157356 ],
        [-0.14541245, -0.14106178, -0.20046997, ..., -0.60107803,
         -0.5806999 , -0.5200424 ],
        [ 0.03437614, -0.01860619, -0.1291542 , ..., -0.61279106,
         -0.5868416 , -0.55138206],
        [-0.03416824, -0.07881355, -0.139431  , ..., -0.5768242 ,
         -0.56368065, -0.5451031 ],
        [-0.11306   , -0.14630127, -0.18651962, ..., -0.47527504,
         -0.48386002, -0.49680328]],

       [[-0.29540953, -0.25229773, -0.21316402, ..., -0.6501789 ,
         -0.5796814 , -0.58689374],
        [-0.18128014, -0.12417793, -0.13654137, ..., -0.6904233 ,
         -0.68461037, -0.64244586],
        [-0.09715843, -0.08390108, -0.10546494, ..., -0.7069289 ,
         -0.6881733 , -0.6722056 ],
        [-0.18694179, -0.16128285, -0.128987  , ..., -0.64433545,
         -0.62889546, -0.6225446 ],
        [-0.27703476, -0.2525959 , -0.20511119, ..., -0.517519  ,
...
          0.51037025,  0.44631258],
        [ 0.31214967,  0.4855779 ,  0.7164224 , ...,  0.4436461 ,
          0.3200194 ,  0.2053426 ],
        [ 0.39565277,  0.5145791 ,  0.7320716 , ...,  0.39797845,
          0.23362541,  0.08429018],
```

```
       [ 0.44386673,  0.44989267,  0.5983505 , ...,  0.5368557 ,
         0.3789749 ,  0.21928024],
       [ 0.42669234,  0.40143776,  0.4725081 , ...,  0.714798  ,
         0.5879669 ,  0.46769652]],

      [[ 0.32543087,  0.3451271 ,  0.4029932 , ...,  0.51263714,
         0.4383192 ,  0.36778736],
       [ 0.42484474,  0.5078449 ,  0.57851505, ...,  0.34471035,
         0.22703075,  0.10994244],
       [ 0.5032301 ,  0.5828867 ,  0.66394806, ...,  0.27353382,
         0.13096333, -0.00620747],
       [ 0.46020794,  0.49208736,  0.58321095, ...,  0.37838078,
         0.25306892,  0.11438084],
       [ 0.3544016 ,  0.36249638,  0.44186687, ...,  0.5236778 ,
         0.4169016 ,  0.31012917]]], dtype=float32)
```

▼ Coordinates:

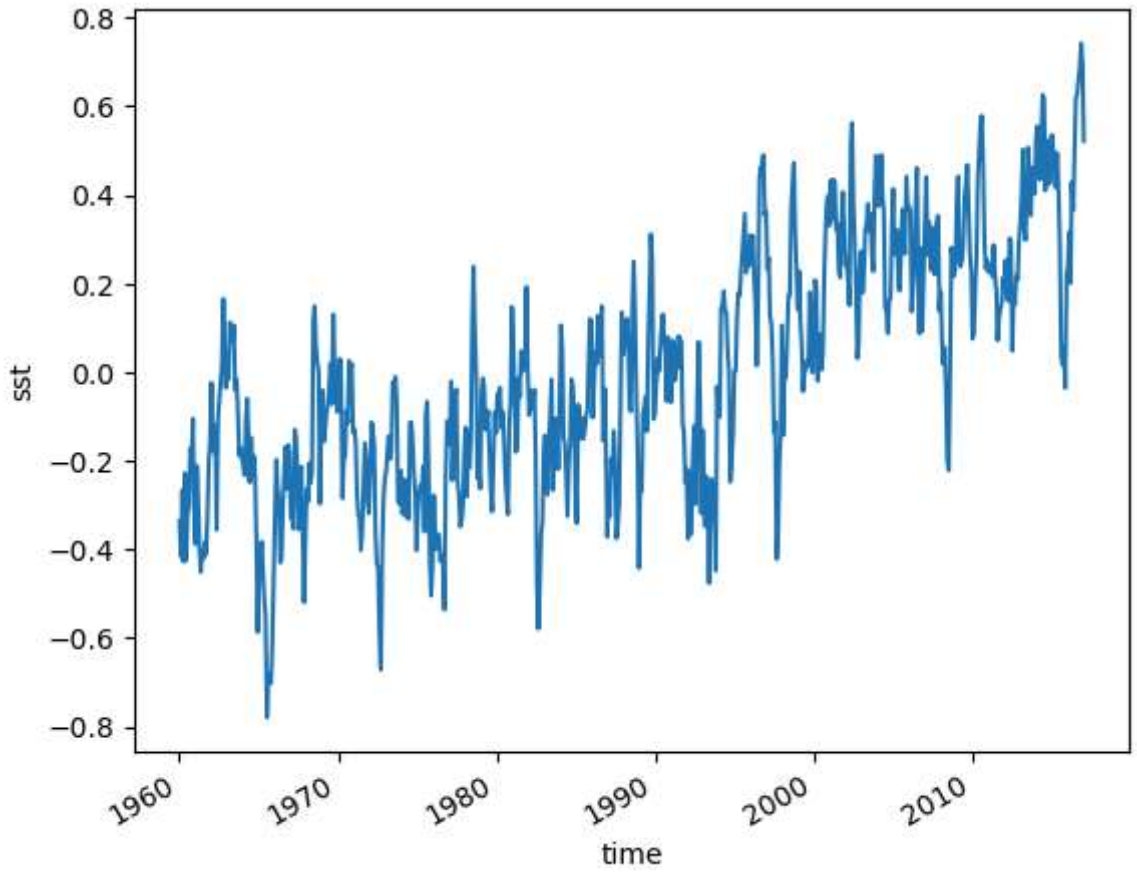
lat	(lat)	float32	-4.0 -2.0 0.0 2.0 4.0	
lon	(lon)	float32	120.0 122.0 124.0 ... 168.0 170.0	
time	(time)	datetime64[ns]	1960-01-31 ... 2017-01-31	

► Indexes: (3)

► Attributes: (0)

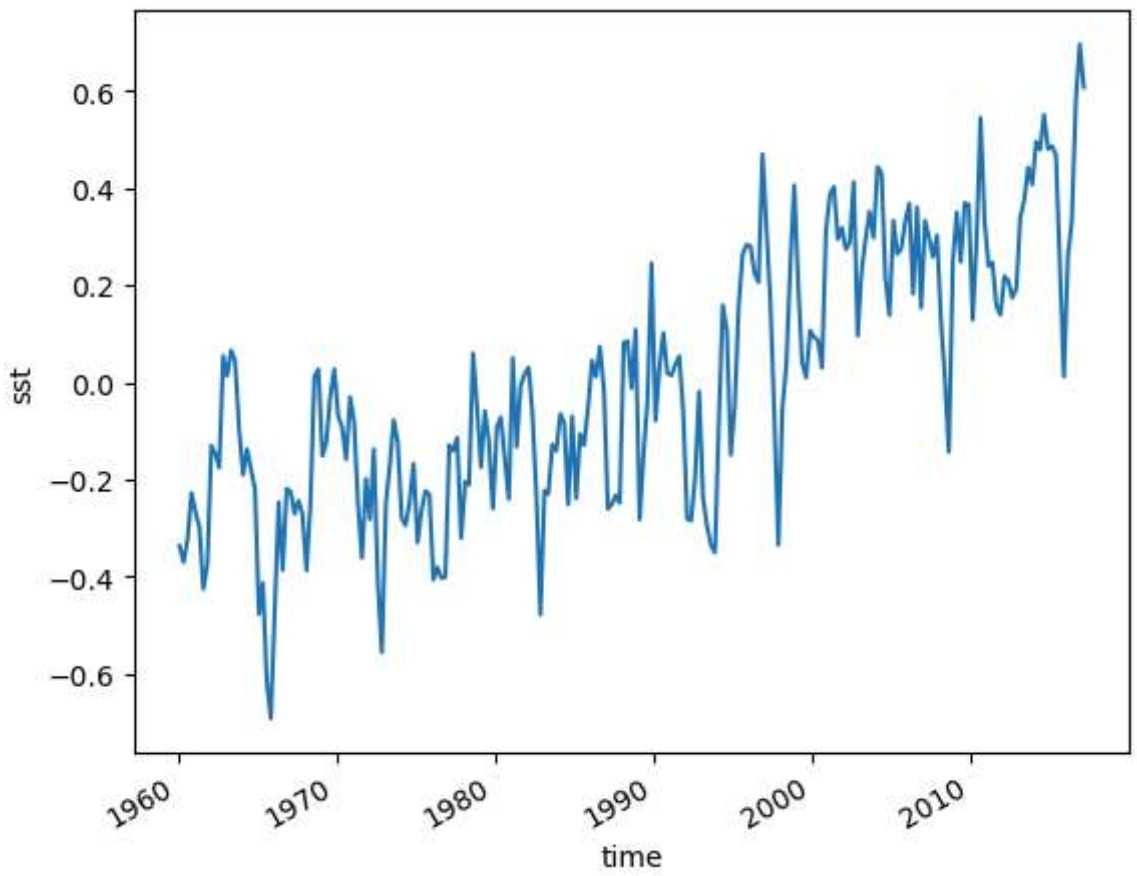
In [53]:
```
# 2.2可视化Niño 3.4指数
# 对去季节变化进行可视化
sst_dif.mean(dim=['lat','lon']).plot()
```

Out[53]:
```
[<matplotlib.lines.Line2D at 0x1688c7adf70>]
```



In [54]:
```
# 以三个月为尺度的异常值可视化
anomalies.mean(dim=['lat','lon']).plot()
```

Out[54]:
```
[<matplotlib.lines.Line2D at 0x1688c6490d0>]
```



In [55]:
```
anom_resample=anomalies.mean(dim=['lat','lon'])
anom_resample
```

Out[55]: xarray.DataArray

'sst'

(**time**: 229)

array([-0.33638978, -0.37003502, -0.3239999 , -0.22765496, -0.26742154,
-0.29706082, -0.42516705, -0.3743719 , -0.13013509, -0.14662217,
-0.17526981, 0.05451763, 0.01313595, 0.06591826, 0.04469279,
-0.09537051, -0.19031097, -0.13719894, -0.1779783 , -0.21954633,
-0.47708625, -0.41306534, -0.61572886, -0.6919386 , -0.46526185,
-0.24677637, -0.38609752, -0.21915027, -0.22480527, -0.2702479 ,
-0.2433737 , -0.27216244, -0.38718328, -0.24891156, 0.01236948,
 0.02674307, -0.1512471 , -0.12314105, -0.02989539, 0.02746935,
-0.06977199, -0.09244606, -0.15824564, -0.03030802, -0.08215355,
-0.24998821, -0.36153477, -0.19859119, -0.2819085 , -0.13750277,
-0.41236964, -0.5556232 , -0.2498695 , -0.1719188 , -0.07733187,
-0.12359207, -0.27969757, -0.29421753, -0.2476332 , -0.16733189,
-0.32939062, -0.26420408, -0.22348669, -0.23065028, -0.4060981 ,
-0.38037926, -0.402714 , -0.4010484 , -0.12891535, -0.1408334 ,
-0.11381914, -0.32007325, -0.2045178 , -0.21054327, 0.05988208,
-0.05048161, -0.17434482, -0.05864822, -0.12214249, -0.25969198,
-0.09298059, -0.07176815, -0.1562431 , -0.24005908, 0.05026476,
-0.13279352, -0.00744956, 0.01719128, 0.03076849, -0.06558541,
-0.2355391 , -0.47826445, -0.22260715, -0.22947134, -0.12784567,
-0.14085631, -0.06479608, -0.08387943, -0.2515224 , -0.06982005,
...
-0.19591552, -0.01864021, -0.23917682, -0.29464397, -0.33528358,
-0.35045642, -0.07411855, 0.15897055, 0.10697694, -0.14921309,
-0.04572915, 0.1568192 , 0.2641609 , 0.28375474, 0.2797301 ,
 0.22447583, 0.20625184, 0.4701414 , 0.31612307, 0.16429943,
-0.07111615, -0.33452275, -0.05399809, 0.03474595, 0.23891602,

0.40586895, 0.20059861, 0.04168706, 0.01015314, 0.10702178,
0.09294897, 0.0868701 , 0.03048421, 0.31326863, 0.38727093,
0.40259364, 0.29476655, 0.3183891 , 0.27422825, 0.28749415,
0.4125064 , 0.09602283, 0.23268497, 0.294751 , 0.35175908,
0.2979943 , 0.4437765 , 0.4319937 , 0.21467721, 0.13865069,
0.33312672, 0.26419055, 0.2758488 , 0.33165234, 0.36844757,
0.18227148, 0.3608378 , 0.15332824, 0.33264446, 0.2980027 ,
0.2584041 , 0.30271897, 0.12783696, 0.01041856, -0.14296326,
0.25190043, 0.3500043 , 0.2480731 , 0.36936525, 0.36543158,
0.12898877, 0.29491633, 0.54474586, 0.3310301 , 0.23948544,
0.24682468, 0.15716833, 0.13909237, 0.21837936, 0.209491 ,
0.17454773, 0.19300571, 0.34000415, 0.3749026 , 0.442632 ,
0.40747023, 0.4960373 , 0.4790274 , 0.5508579 , 0.48036876,
0.48651356, 0.469067 , 0.24312 , 0.01210874, 0.25750467,
0.33146283, 0.57795835, 0.6961747 , 0.6076585], dtype=float32)

▼ Coordinates:

time	(time)	datetime64[ns]	1960-01-31 ... 2017-01-31

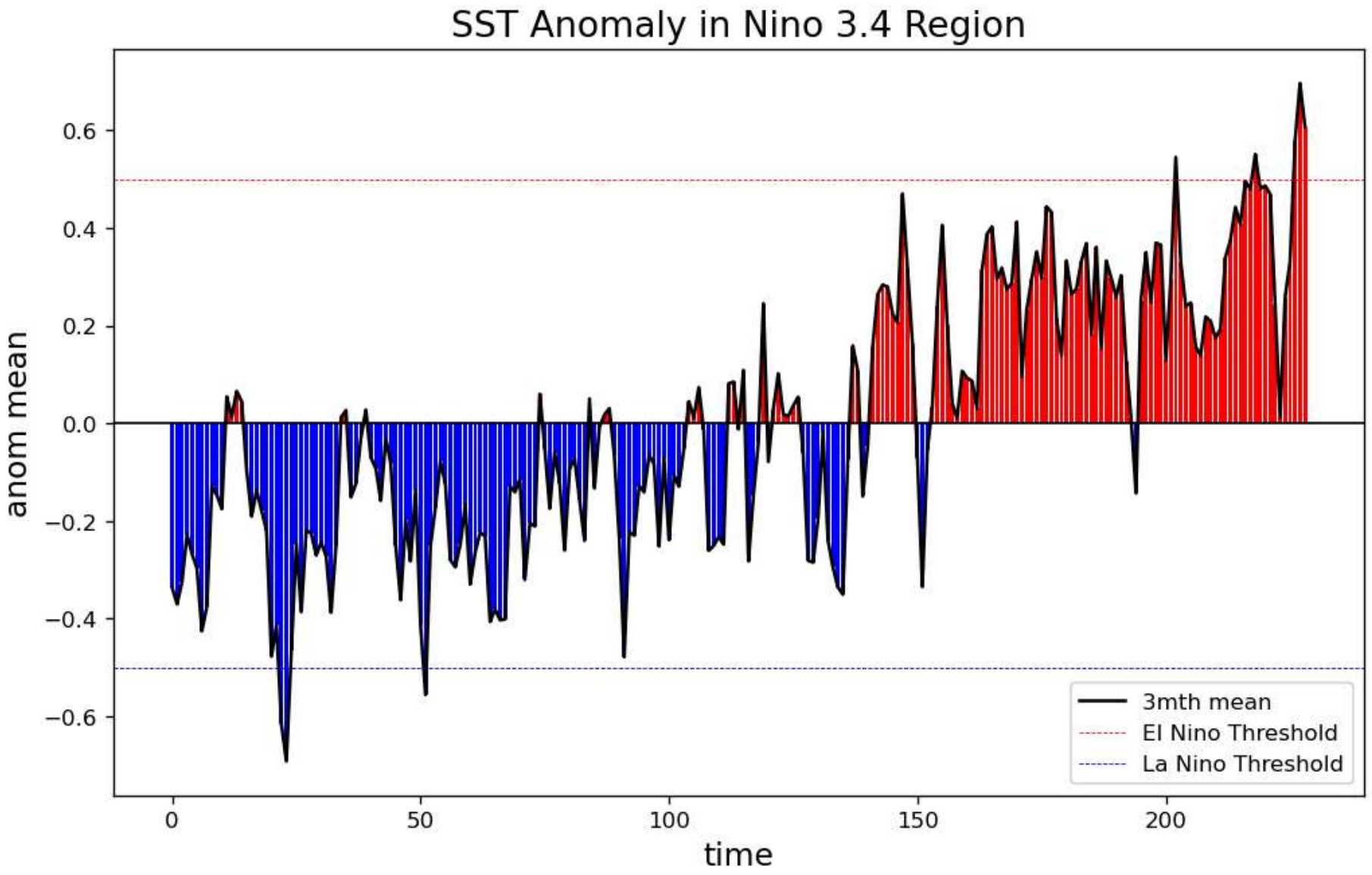
► Indexes: (1)

► Attributes: (0)

In [75]:
```
# 创建一个DataFrame，其中只包含温度异常大于等于0的数据，并命名为'anom>=0'
df=pd.DataFrame(anom_resample.where(anom_resample>=0),columns=['anom>=0'])

# 创建一个DataFrame，其中包含温度异常小于0的数据，并命名为'anom<0'
df['anom<0']=pd.DataFrame(anom_resample.where(anom_resample<0))
df['date'] = pd.DataFrame(anom_resample.time)
df.set_index('date',inplace=True)

# 根据正负进行柱状图的绘制与上色
plt.figure(figsize=(10,6),dpi=120)
plt.bar(np.arange(len(df['anom>=0'])),df['anom>=0'],color="red")
plt.bar(np.arange(len(df['anom<0'])),df['anom<0'],color="blue")
```

```
# 绘制原始温度异常数据的折线图，颜色为黑色
plt.plot(anom_resample,'k-')

# 作出0，0.5，-0.5三条线，设置图例
plt.axhline(y=0.5,color="red",linestyle='--',linewidth=0.5)
plt.axhline(y=-0.5,color="blue",linestyle='--',linewidth=0.5)
plt.axhline(y=0,color="black",linestyle='-',linewidth=1)
plt.legend(labels=['3mth mean','EI Nino Threshold','La Nino Threshold'],loc=4)
plt.ylabel('anom mean',fontsize=14)
plt.xlabel('time',fontsize=14)
plt.title('SST Anomaly in Nino 3.4 Region',fontsize=16)
```

Out[75]: Text(0.5, 1.0, 'SST Anomaly in Nino 3.4 Region')



数据anom_resample代表重新采样的平均值，绘制异常值大于零的柱状图，颜色为红色；异常值小于零的柱状图，颜色为蓝色。3mth mean的黑实线代表异常值为零，El Nino Threshold的红色虚线代表异常值为0.5，La Nino Threshold的蓝色虚线代表异常值为-0.5。

In [58]:
```python
# 3.Explore a netCDF dataset
# 这里我向陈怡学习了如何导入文件
import xarray as xr
import glob
# 定义文件路径
file='D:\\ESE5023-Assignments-12432892\\output_file\\*.nc4'
# 获取所有文件路径
files=glob.glob(file)
# 合并多个文件
CO2=xr.open_mfdataset(files,combine='by_coords')
# 查看合并后的文档
CO2
```

Out[58]: xarray.Dataset

► Dimensions: (**lat**: 361, **lon**: 576, **time**: 86)

▼ Coordinates:

lat	(lat)	float64	-90.0 -89.5 -89.0 ... 89.5 90.0
lon	(lon)	float64	-180.0 -179.4 ... 178.8 179.4
time	(time)	datetime64[ns]	2015-01-16T12:00:00 ... 2022-02-15

▼ Data variables:

XCO2	(time, lat, lon)	float64	dask.array<chunksize=(1, 361, 576), met...
XCO2PREC	(time, lat, lon)	float64	dask.array<chunksize=(1, 361, 576), met...

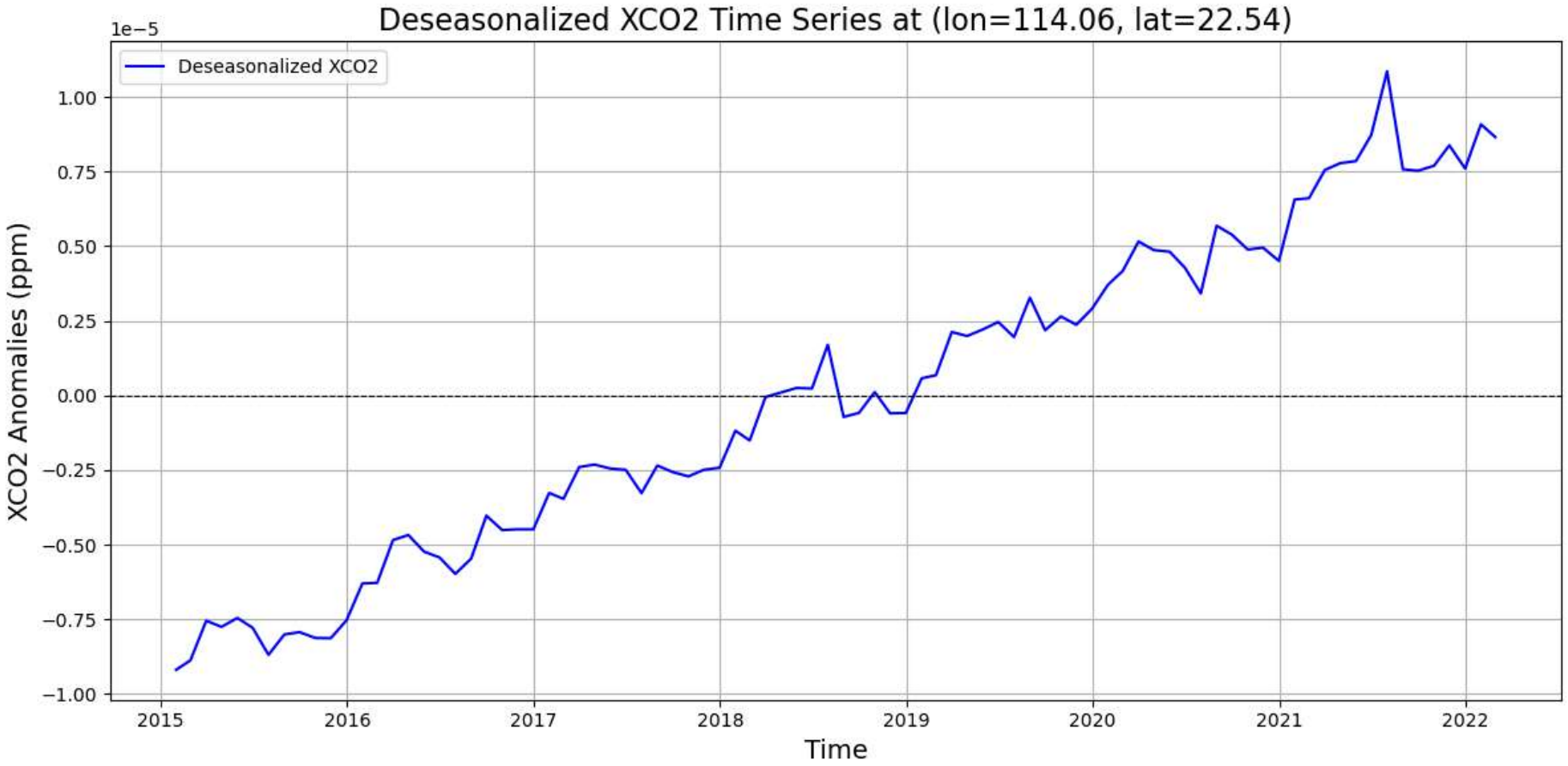
► Indexes: (3)

► Attributes: (25)

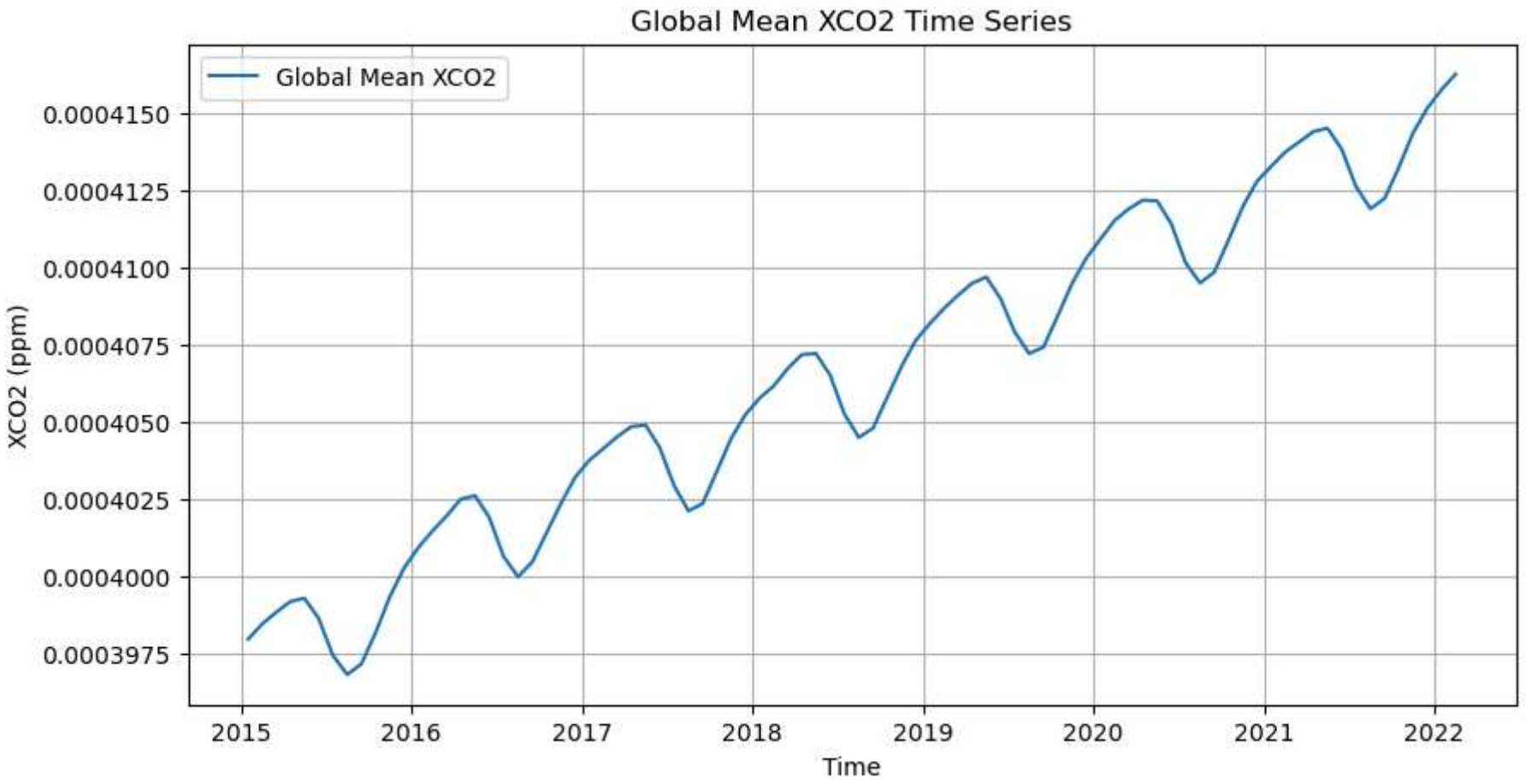
In [73]:
```python
# 3.1 本题我请教了陈怡同学
# 根据数据文件，我绘制了我的家乡哈尔滨市（126.53°E，45.75°N）的XCO2的时间序列

# 根据数据集中的经纬度信息选择哈尔滨市的数据
xco2_selected = CO2['XCO2'].sel(lon=126.53, lat=45.75, method='nearest')

# 计算哈尔滨市每月XCO2的平均值，用于表示季节性成分
```

```python
monthly_mean = xco2_selected.groupby('time.month').mean(dim='time')

# 从原始数据中去除季节性成分，得到去季节化后的异常值
xco2_deseasonalized = xco2_selected - monthly_mean[xco2_selected['time.month'] - 1]

# 获取时间序列
time_series = xco2_deseasonalized.resample(time='M').mean()  # 按月重采样

# 绘制去季节化后的时间序列
plt.figure(figsize=(12, 6))
plt.plot(time_series['time'], time_series, label='Deseasonalized XCO2', color='blue')
plt.axhline(0, color='black', linestyle='--', linewidth=0.8)  # 添加黑色的虚线作为参考线
plt.title('Deseasonalized XCO2 Time Series at (lon=114.06, lat=22.54)', fontsize=16)
plt.xlabel('Time', fontsize=14)
plt.ylabel('XCO2 Anomalies (ppm)', fontsize=14)
plt.legend()
plt.grid()
plt.tight_layout()
plt.show()
```

```
D:\python111\Lib\site-packages\xarray\core\groupby.py:508: FutureWarning: 'M' is deprecated and will be removed in a future ver
sion, please use 'ME' instead.
  index_grouper = pd.Grouper(
```



In [93]:
```python
# 3.2.1
#时间序列图：全球平均XCO2
global_mean_xco2 = CO2['XCO2'].mean(dim=['lat', 'lon'])
plt.figure(figsize=(10, 5))
plt.plot(global_mean_xco2['time'], global_mean_xco2, label='Global Mean XCO2')
plt.title('Global Mean XCO2 Time Series')
plt.xlabel('Time')
plt.ylabel('XCO2 (ppm)')
plt.legend()
plt.grid()
plt.show()
```

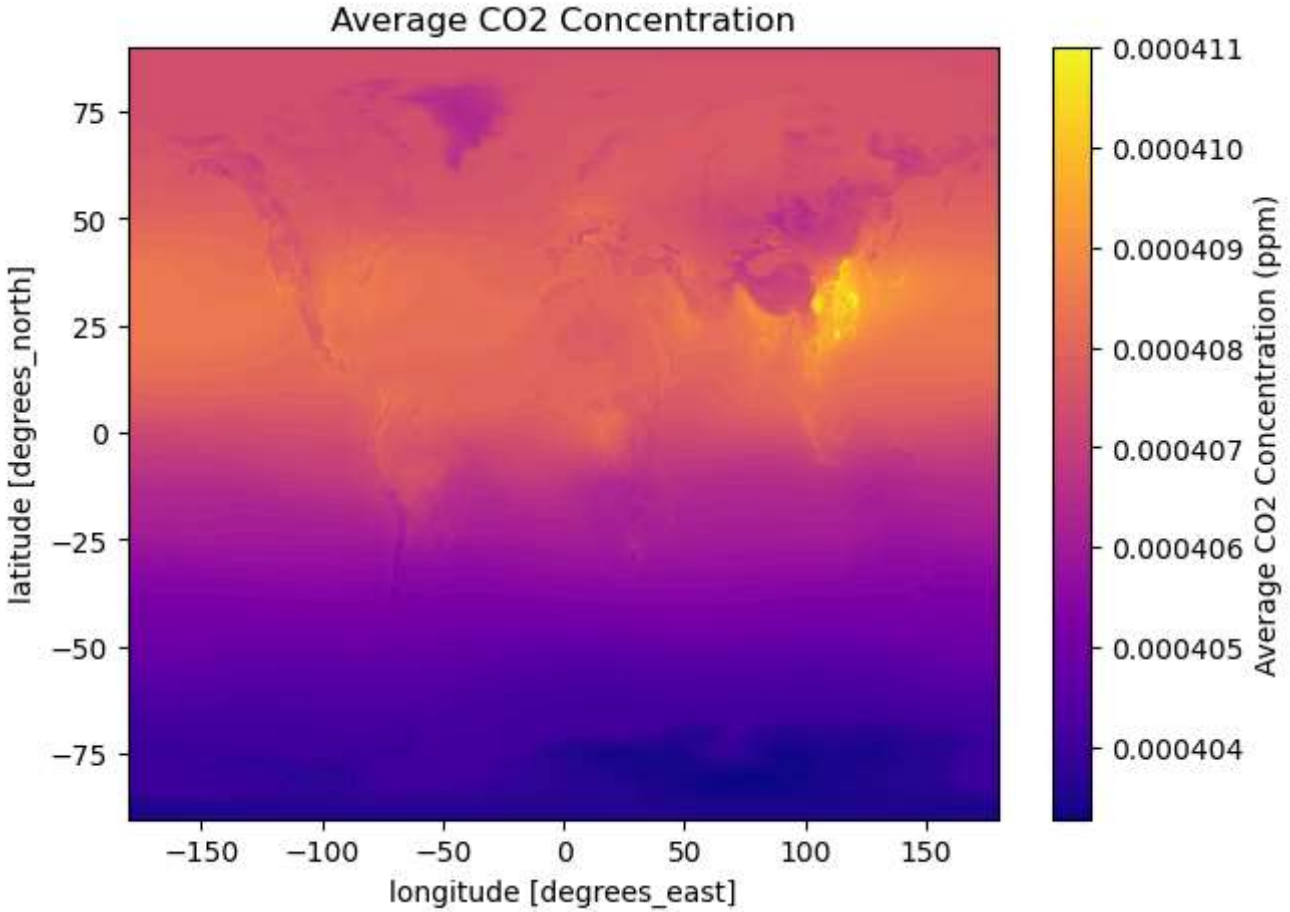


In [127…

```
# 3.2.2
# 计算XCO2的平均浓度在不同地点的变化
xco2 = CO2['XCO2']
# 计算 XCO2的整体平均值，按照时间维度
xco2_mean = xco2.mean(dim='time')
#设置图象大小
plt.figure(figsize=(7, 5))
# 绘制 XCO2 的整体平均值
xco2_mean.plot(cmap='plasma', cbar_kwargs={'label': 'Average CO2 Concentration (ppm)'})
plt.title('Average CO2 Concentration')
```

Out[127…

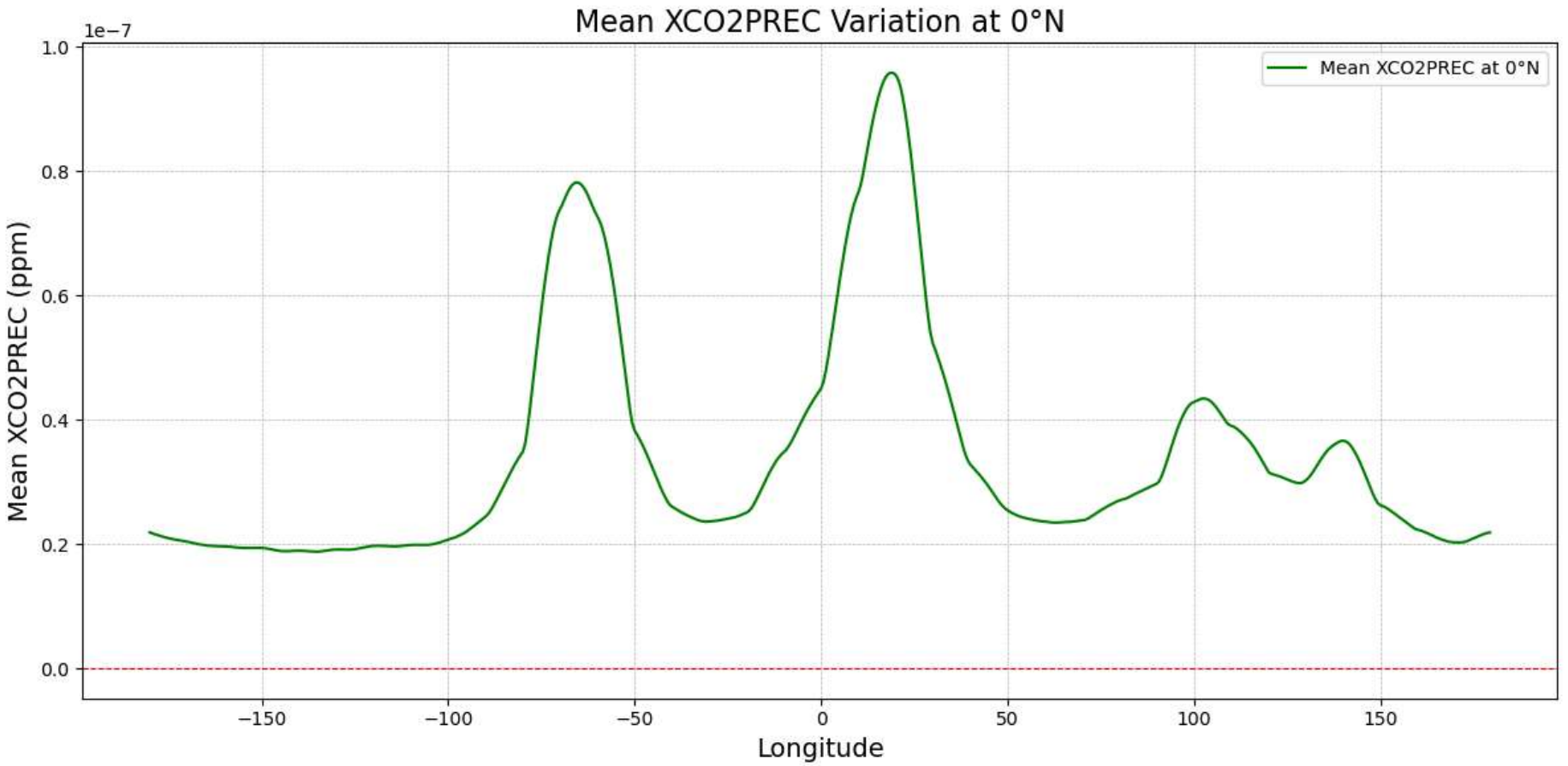
```
Text(0.5, 1.0, 'Average CO2 Concentration')
```



In [133…

```
# 3.2.3
# 绘制在 0°纬度线上 XCO2PREC的均值变化

# 选择纬度为0°的数据
xco2_actual_0N = xco2_actual.sel(lat=0, method='nearest')

# 计算 XCO2PREC的时间平均值
xco2_actual_mean = xco2_actual_0N.mean(dim='time')

# 绘制 XCO2PREC在0°纬度的平均值变化
plt.figure(figsize=(12, 6))
xco2_actual_mean.plot(label='Mean XCO2PREC at 0°N', color='green')
```

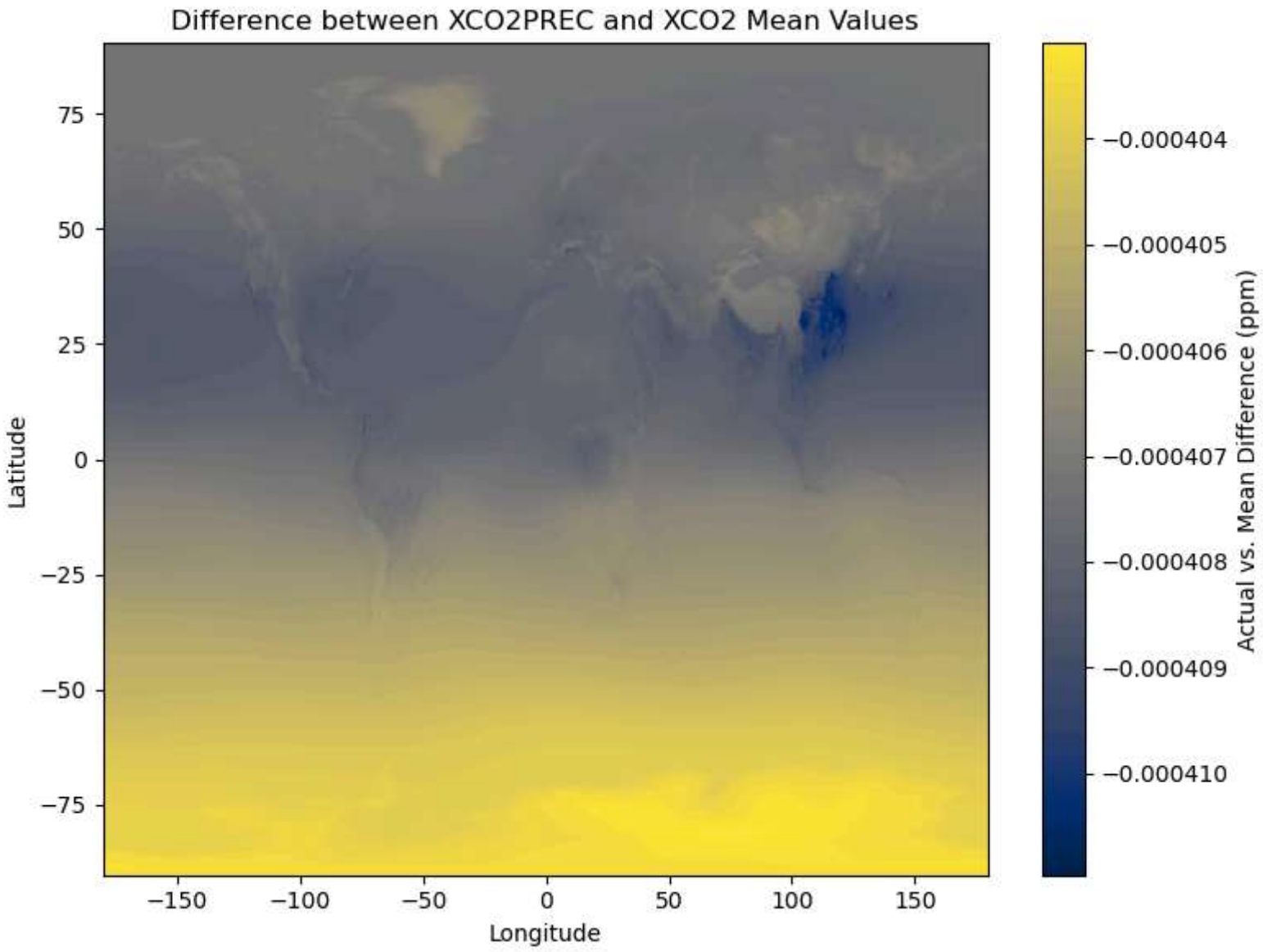
```
plt.title('Mean XCO2PREC Variation at 0°N', fontsize=16)
plt.xlabel('Longitude', fontsize=14)
plt.ylabel('Mean XCO2PREC (ppm)', fontsize=14)
# 添加水平线（0线）
plt.axhline(0, color='red', linestyle='--', linewidth=0.8)
plt.legend()
plt.grid(True, linestyle='--', linewidth=0.5)
plt.tight_layout()
plt.show()
```



In [129…

```
# 3.2.4
# 计算XCO2值与XCO2PREC值的差异
xco2_actual = CO2['XCO2PREC']
```

```
# 计算XCO2PREC的平均值
xco2_actual_mean = xco2_actual.mean(dim='time')
# 计算二者之间的差异
difference = xco2_prec_mean - xco2_mean
# 绘制图形
plt.figure(figsize=(8, 6))
difference.plot(cmap='cividis', cbar_kwargs={'label': 'Actual vs. Mean Difference (ppm)'})
plt.title('Difference between XCO2PREC and XCO2 Mean Values')
plt.xlabel('Longitude')
plt.ylabel('Latitude')
plt.tight_layout()
plt.show()
```



In [137…

```
# 3.2.5
# 选择北京的XCO2数据，北京（假设纬度为39.9，经度为116.4）
xco2_beijing = CO2['XCO2'].sel(lat=39.9, lon=116.4, method='nearest')

# 绘制XCO2浓度随时间变化图
```

```
plt.figure(figsize=(10, 5))
xco2_beijing.plot()
plt.title('XCO2 Concentration Over Time in Beijing')
plt.xlabel('Time')
plt.ylabel('XCO2 (ppm)')
plt.show()
```