In [2]:

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

In [3]:

```
# Load modules
import numpy as np
import pandas as pd
import matplotlib as mpl
import matplotlib.pyplot as plt
import matplotlib.gridspec as gridspec
```

In [3]:

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

Out[3]:

xarray.Dataset

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

▼ Coordinates:

time	(time)	datetime64[ns]	2003-01-16T12:00:…
lat	(lat)	float64	-87.5 -82.5 -77.5 ……
lon	(lon)	float64	-177.5 -172.5 ... 17…

▼ 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_averagi…	(time, pressure, lat, lon)	float32	...
vmr_profile_ch4…	(time, pressure, lat, lon)	float32	...

▶ Attributes: (28)

In [4]:

```
ds['xch4']
```

Out[4]:

xarray.DataArray 'xch4' (**time**: 210, **lat**: 36, **lon**: 72)

[544320 values with dtype=float32]

▼ Coordinates:

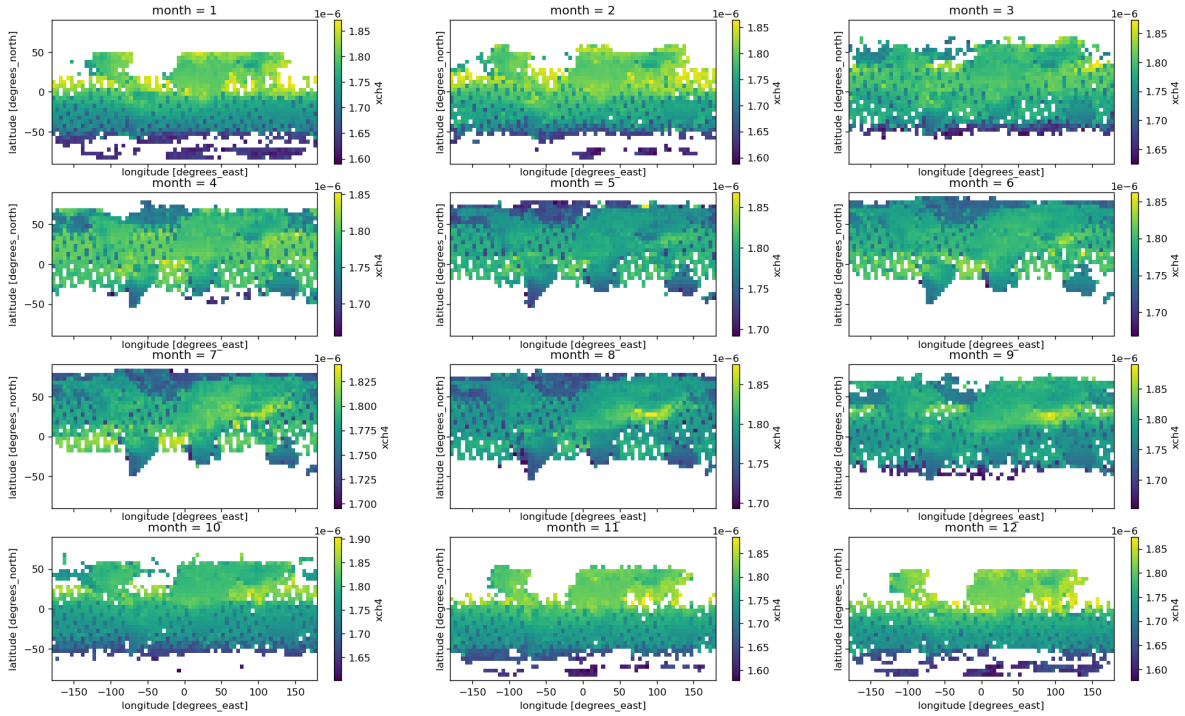
time	(time)	datetime64[ns]	2003-01-16T12:00:00 ... 2020-06-16
lat	(lat)	float64	-87.5 -82.5 -77.5 ... 82.5 87.5
lon	(lon)	float64	-177.5 -172.5 ... 172.5 177.5

▼ Attributes:

standard_name :	dry_atmosphere_mole_fraction_of_methane
long_name :	column-average dry-air mole fraction of atmospheric methane
units :	1
cell_methods :	time: mean
fill_value :	1e+20
comment :	Satellite retrieved column-average dry-air mole fraction of atmospheric methane (XCH4)

In [144]:

```
#1.1
#取出月平均
m=ds.xch4.groupby('time.month').mean()
#创建12幅表格
fig,axes=plt.subplots(4,3,figsize=(20,12),sharex=True,sharey=True,dpi=120)
#借鉴袁文婷，拉成一维数组
axes=axes.ravel()
#创建for loop将各月份填入其中
for i in range(12):
    axes[i]=plt.subplot(4,3,i+1)
    m[i,:,:].plot()
```

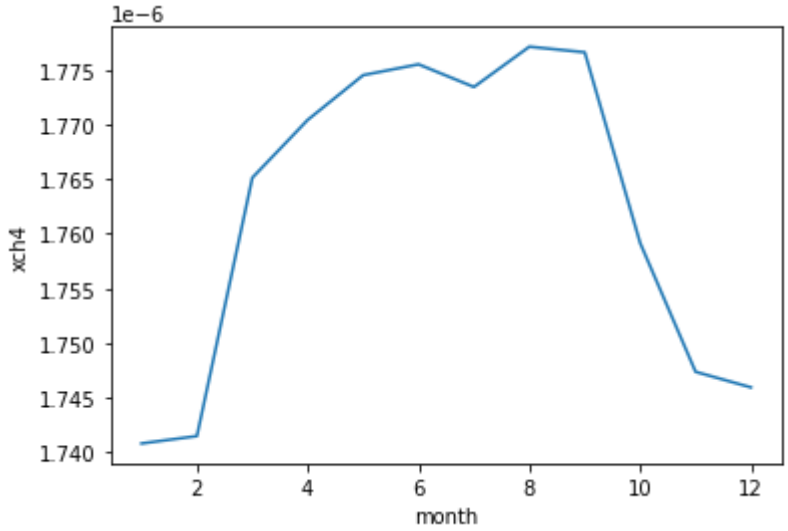


In [65]:

```
#CH4按月变化趋势
xch4_clim.mean(dim='lon').mean(dim='lat').transpose().plot()
```

Out[65]:

[<matplotlib.lines.Line2D at 0x2492d085e20>]

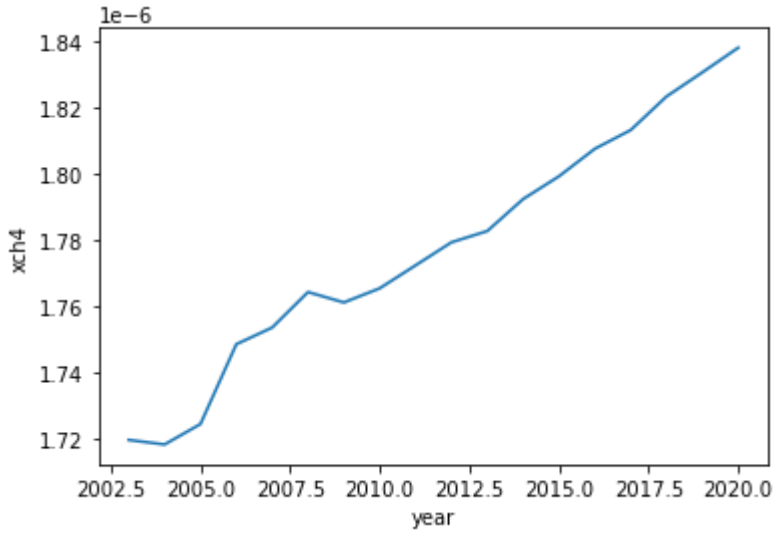


In [145]:

```
#1.2
#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
ds.xch4.groupby(ds.time.dt.year)
xch4_year=ds.xch4.groupby('time.year').mean()
xch4_year.mean(dim=['lon','lat']).transpose().plot()
```

Out[145]:

```
[<matplotlib.lines.Line2D at 0x252315716d0>]
```



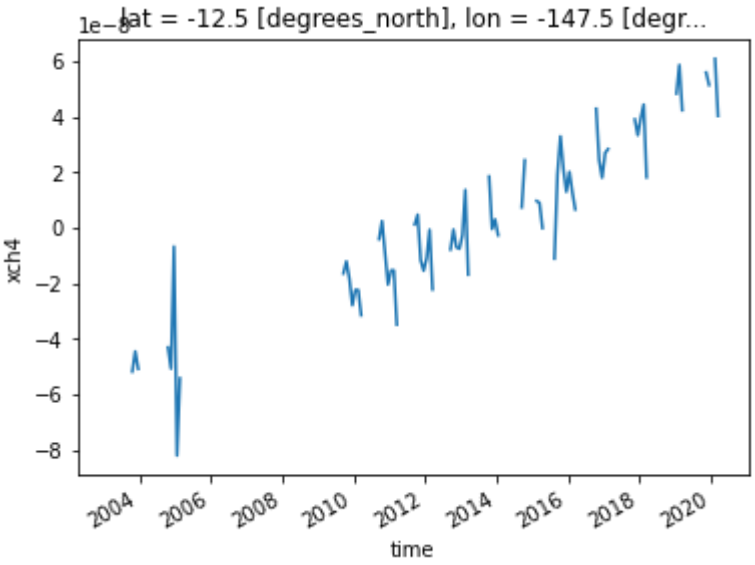
In [88]:

```
#1.3
#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
group_data=ds.xch4.groupby('time.month')
xch4_anom=group_data-group_data.mean(dim='time')
xch4_anom.sel(lon=-150,lat=-15,method='nearest').plot()
```

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

Out[88]:

```
[<matplotlib.lines.Line2D at 0x2492eb7e0a0>]
```



In [4]:

```
#2
SST=xr.open_dataset("NOAA_NCDC_ERSST_v3b_SST.nc",engine='netcdf4')
SST
```

Out[4]:

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 35…	
time	(time)	datetime64[ns]	1960-01-15 ... 2016-12-15	

▼ Data variables:

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

▼ 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 [5]:

```
SST['sst']
```

Out[5]:

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	

▼ 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:hasSemanti…	iridl:SeaSurfaceTemperature

In [6]:

```
#2.1
#在(5N-5S, 170W-120W)处计算温度的季节性变化
sst_clim=SST.sst.sel(lon=slice(120,170),lat=slice(-5,5)).groupby('time.month').mean()
sst_clim
```

Out[6]:

xarray.DataArray 'sst' (**month**: 12, **lat**: 5, **lon**: 26)

```
array([[[29.028156, 29.124018, 29.130487, ..., 29.458986, 29.40671 ,
         29.358635],
        [29.027426, 29.153624, 29.129362, ..., 29.291643, 29.204933,
         29.120565],
        [28.849007, 28.912628, 28.852278, ..., 29.110067, 28.99955 ,
         28.881413],
        [28.612465, 28.634708, 28.546515, ..., 29.011509, 28.898874,
         28.79206 ],
        [28.40417 , 28.447857, 28.392477, ..., 28.926332, 28.847929,
         28.770119]],

       [[28.825596, 28.930664, 28.940992, ..., 29.35216 , 29.293056,
         29.238314],
        [28.833675, 28.988573, 28.985886, ..., 29.194006, 29.0958  ,
         28.999252],
        [28.68234 , 28.760672, 28.715094, ..., 29.009357, 28.88335 ,
         28.75082 ],
        [28.4706  , 28.487507, 28.394753, ..., 28.928986, 28.801754,
         28.684416],
        [28.25052 , 28.287918, 28.223717, ..., 28.879599, 28.797909,
...
         29.634012],
        [29.52841 , 29.521248, 29.439075, ..., 29.461407, 29.411896,
         29.378262],
        [29.469206, 29.49123 , 29.416918, ..., 29.265162, 29.185635,
         29.129591],
        [29.35844 , 29.388475, 29.340836, ..., 29.25499 , 29.164148,
         29.110823],
        [29.258398, 29.272776, 29.248367, ..., 29.318436, 29.257198,
         29.215263]],

       [[29.398111, 29.451107, 29.452528, ..., 29.62688 , 29.598337,
         29.573372],
        [29.383438, 29.455273, 29.41713 , ..., 29.432829, 29.369019,
         29.315294],
        [29.23622 , 29.28212 , 29.224049, ..., 29.233976, 29.140806,
         29.057495],
        [29.042618, 29.06313 , 28.99859 , ..., 29.160395, 29.058783,
         28.97982 ],
        [28.894953, 28.918709, 28.872938, ..., 29.127762, 29.056019,
         28.993029]]], 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
month	(month)	int64	1 2 3 4 5 6 7 8 9 10 11 12

► Attributes: (0)

In [7]:

```
#进行去季节化，得到异常值
group_data=SST.sst.sel(lon=slice(120,170),lat=slice(-5,5)).groupby('time.month')
sst_anom=group_data-group_data.mean(dim='time')
sst_anom.sel(lon=slice(120,170),lat=slice(-5,5))
#对数据进行处理以三个月为尺度得到异常值
resample_obj = sst_anom.resample(time="3M")
ds_anom_resample = resample_obj.mean(dim="time")
ds_anom_resample
```

Out[7]:

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:

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

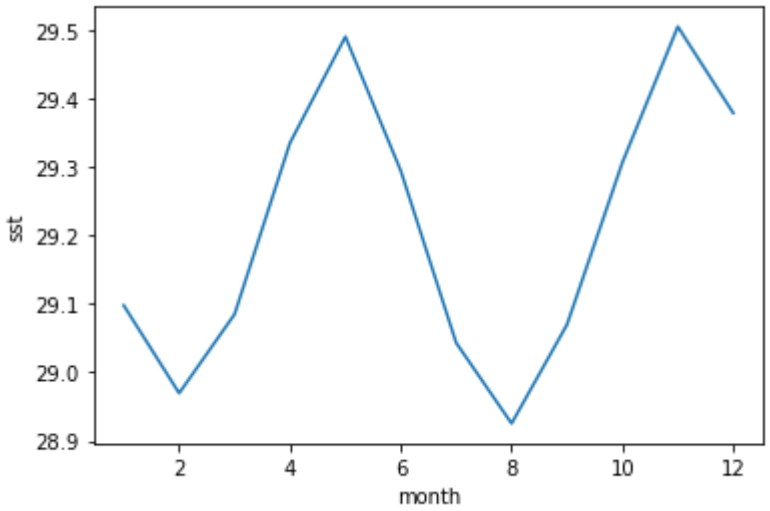
► Attributes: (0)

In [8]:

```
#2.2
#对季节性变化进行可视化
sst_clim.mean(dim=['lat','lon']).plot()
```

Out[8]:

```
[<matplotlib.lines.Line2D at 0x20ee453bd30>]
```

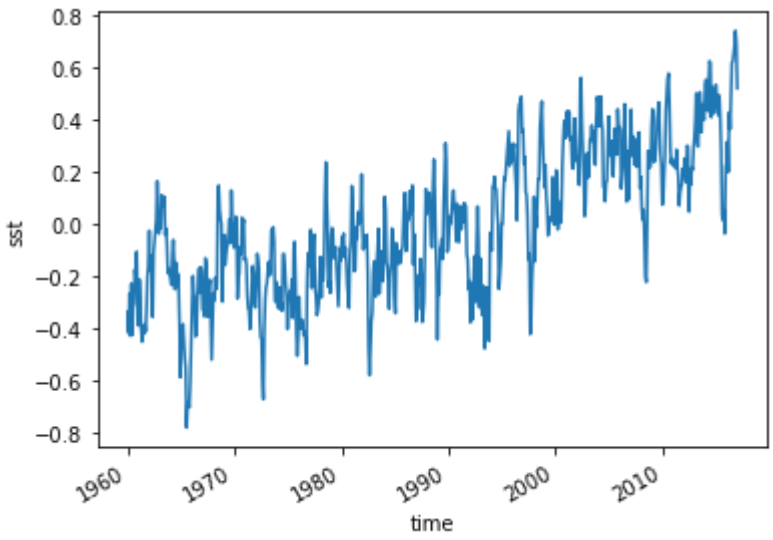


In [9]:

```
#对去季节性变化进行可视化
sst_anom.mean(dim=['lat','lon']).plot()
```

Out[9]:

```
[<matplotlib.lines.Line2D at 0x20ee4c9d1f0>]
```

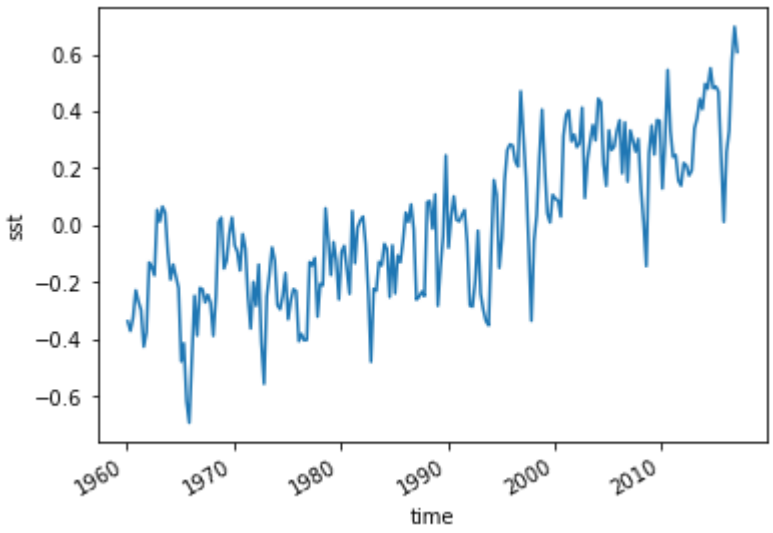


In [10]:

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

Out[10]:

```
[<matplotlib.lines.Line2D at 0x20ee4d24370>]
```



In [33]:

```
ds_anom_resample_m=ds_anom_resample.mean(dim=['lat','lon'])
ds_anom_resample_m
```

Out[33]:

xarray.DataArray 'sst' (**time**: 229)

-0.3364 -0.37 -0.324 -0.2277 -0.2674 ... 0.3315 0.578 0.6962 0.6077

▼ Coordinates:

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

► Attributes: (0)

In [40]:

```
#上色及划线部分参考袁文婷同学
df=pd.DataFrame(ds_anom_resample_m.where(ds_anom_resample_m>=0),columns=['anom>=0'])
df['anom<0']=pd.DataFrame(ds_anom_resample_m.where(ds_anom_resample_m<0))
df['date'] = pd.DataFrame(ds_anom_resample_m.time)
df.set_index('date',inplace=True)
df
```

Out[40]:

date	anom>=0	anom<0
1960-01-31	NaN	-0.336390
1960-04-30	NaN	-0.370035
1960-07-31	NaN	-0.324000
1960-10-31	NaN	-0.227655
1961-01-31	NaN	-0.267422
...	...	...
2016-01-31	0.257505	NaN
2016-04-30	0.331463	NaN
2016-07-31	0.577958	NaN
2016-10-31	0.696175	NaN
2017-01-31	0.607659	NaN

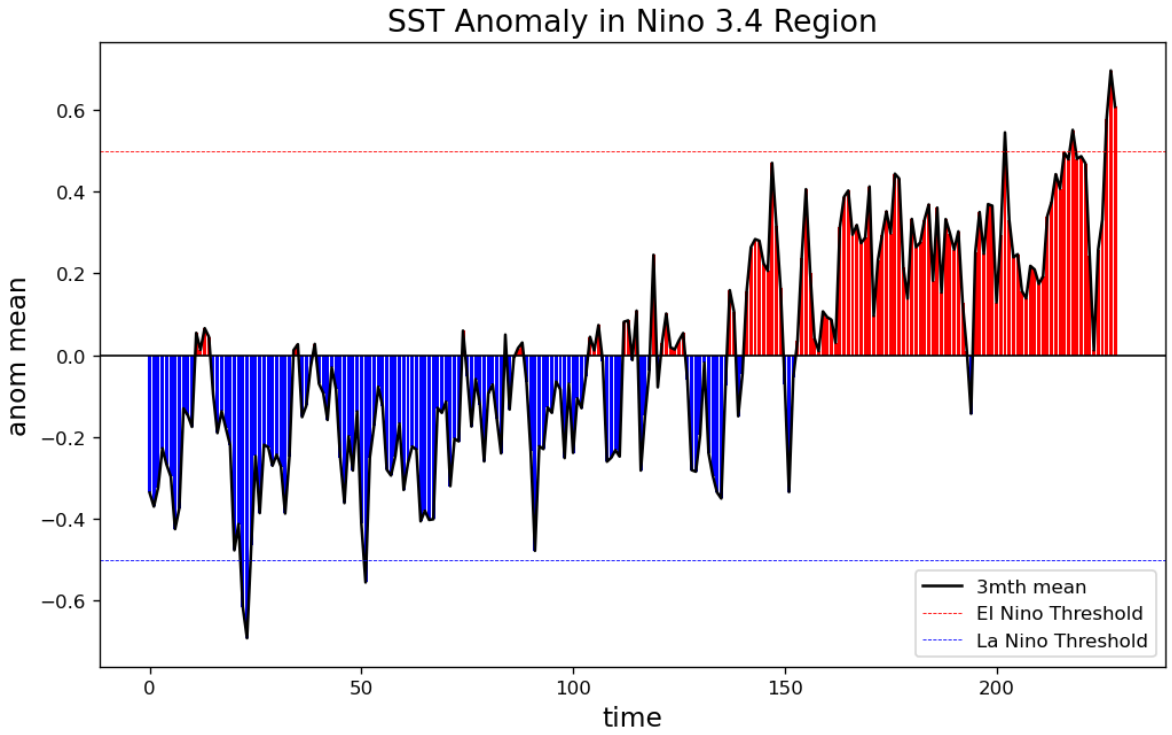
229 rows × 2 columns

In [42]:

```
#根据正负进行上色
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")
plt.plot(ds_anom_resample_m,'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','El 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[42]:

Text(0.5, 1.0, 'SST Anomaly in Nino 3.4 Region')



In [11]:

```
#加载文档，因不知道如何下载所以使用课堂文件
da= xr.open_dataset("sst.mnmean.nc", engine="netcdf4")
da
```

Out[11]:

xarray.Dataset

▶ Dimensions: (**lat**: 89, **lon**: 180, **time**: 2026, nbnds: 2)

▼ 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 35…
time	(time)	datetime64[ns]	1854-01-01 ... 2022-10-01

▼ Data variables:

time_bnds	(time, nbnds)	float64	...
sst	(time, lat, lon)	float32	...

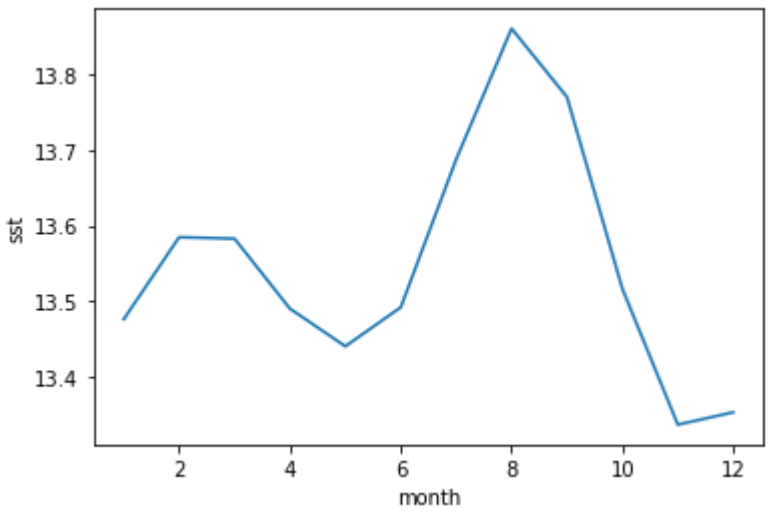
▶ Attributes: (37)

In [12]:

```
#3.1
#制作出sst的季节性变化
sst_climm=da.sst.groupby("time.month").mean()
sst_climm.mean(dim=['lon','lat']).plot()
```

Out[12]:

```
[<matplotlib.lines.Line2D at 0x20ee5d8a9a0>]
```

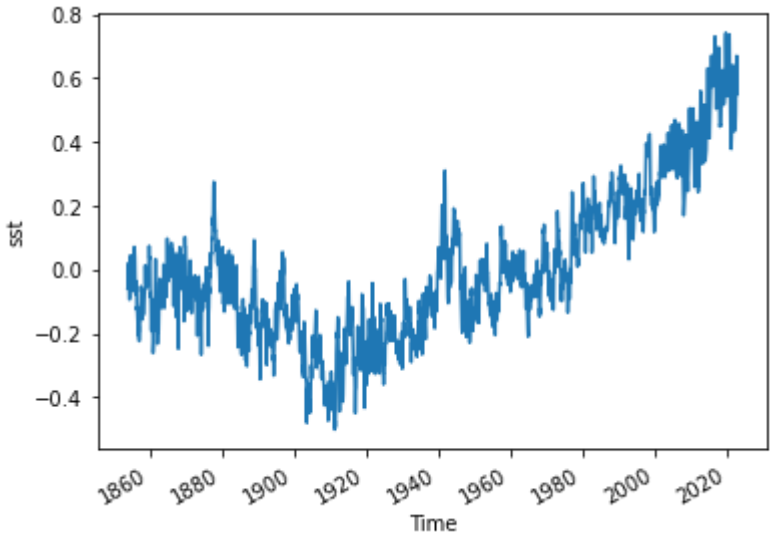


In [14]:

```
#去季节性
group_dataa=da.sst.groupby("time.month")
sst_anomm=group_dataa-group_dataa.mean('time')
sst_anomm.mean(dim=['lon','lat']).plot()
```

Out[14]:

[<matplotlib.lines.Line2D at 0x20ee6e16250>]

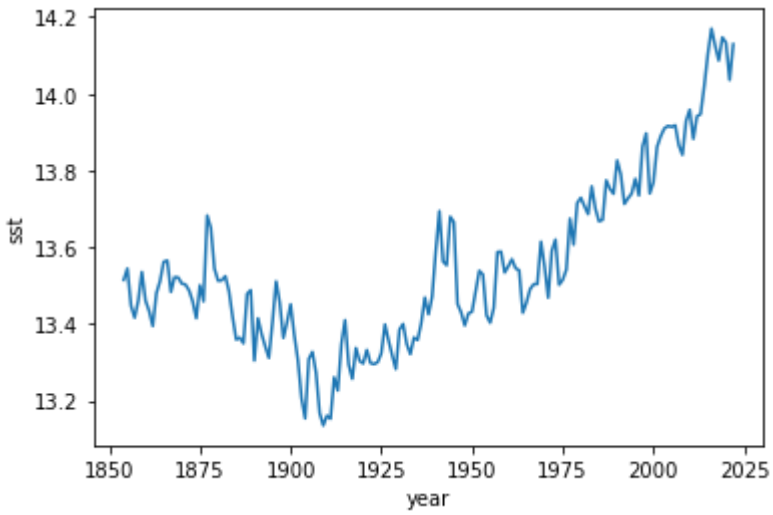


In [13]:

```
#3.2
#sst随年份变化
sst_1=da.sst.groupby("time.year").mean()
sst_1.mean(dim=['lon','lat']).plot()
```

Out[13]:

[<matplotlib.lines.Line2D at 0x20ee6dc3cd0>]

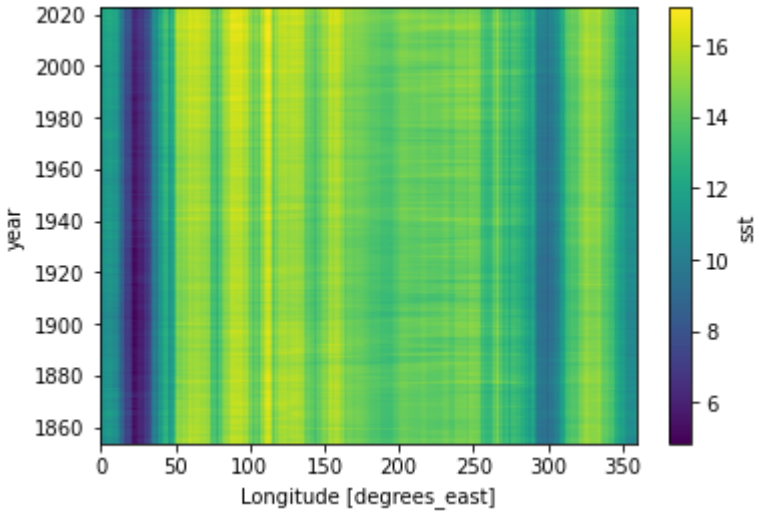


In [15]:

```
#sst随年份和经度变化
sst_1.mean(dim='lat').plot()
```

Out[15]:

<matplotlib.collections.QuadMesh at 0x20ee6ebc130>

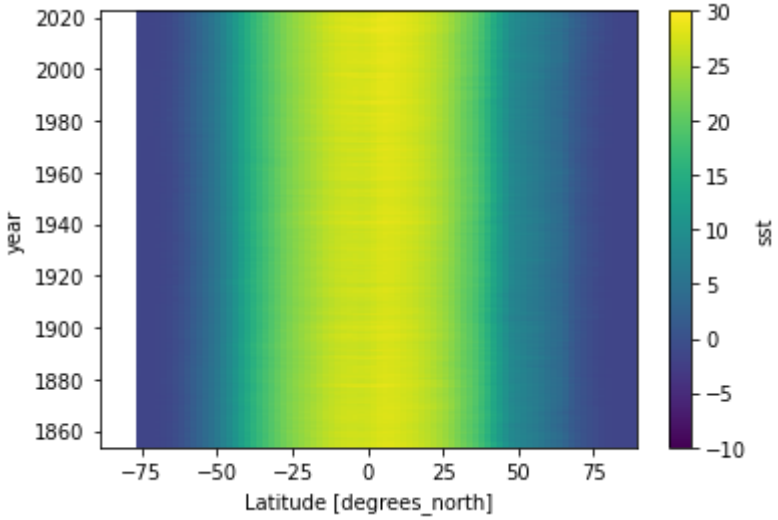


In [21]:

```
#sst随年份和纬度变化
sst_1.mean(dim='lon').plot(vmin=-10,vmax=30)
```

Out[21]:

<matplotlib.collections.QuadMesh at 0x20ee8db1160>

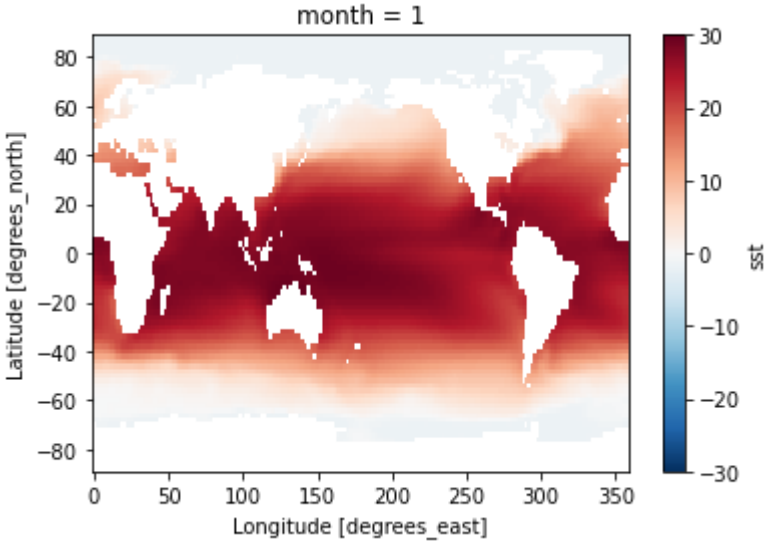


In [23]:

```
#每年一月份温度分布
group_dataa.mean().sel(month=1).plot()
```

Out[23]:

<matplotlib.collections.QuadMesh at 0x20ee8f40910>

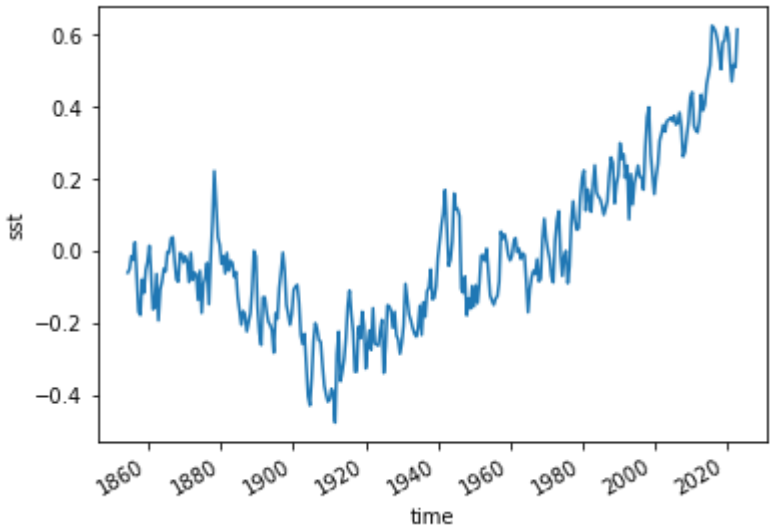


In [26]:

```
#以半年为周期重新处理年度变化
resample_ob = sst_anomm.resample(time="6M")
da_anom_resample = resample_ob.mean(dim="time")
da_anom_resample.mean(dim=['lon','lat']).plot()
```

Out[26]:

```
[<matplotlib.lines.Line2D at 0x20ee9964460>]
```

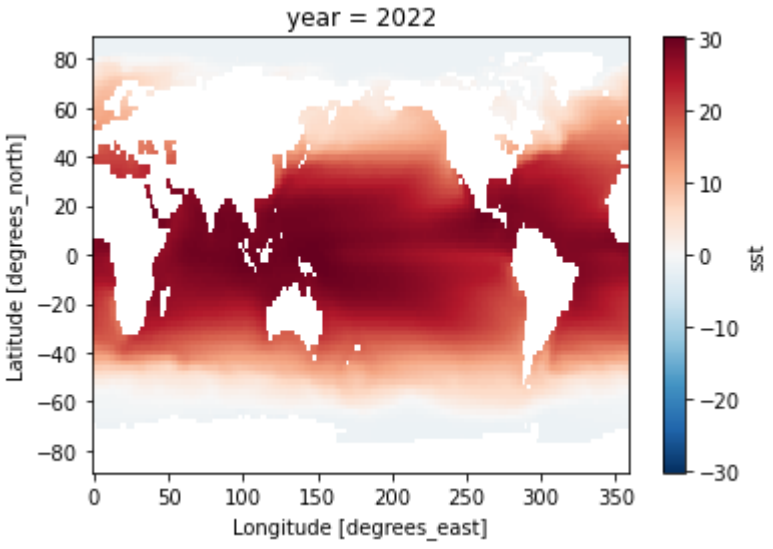


In [30]:

```
#sst在特定时间上的经纬度分布
sst_1.isel(year=-1).plot()
```

Out[30]:

```
<matplotlib.collections.QuadMesh at 0x20eecb9ca00>
```



In [ ]:

```

```