In [1]:
```python
import xarray as xr
%matplotlib inline
import numpy as np
import pandas as pd
import matplotlib as mpl
import matplotlib.pyplot as plt
import matplotlib.gridspec as gridspec
%matplotlib inline
import cartopy.crs as ccrs
import cartopy.feature as cfeature
```

In [2]:
```python
#1
ds = xr.open_dataset("NOAA_NCDC_ERSST_v3b_SST.nc", engine="netcdf4")
ds
```

Out[2]:

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 ... |
| **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 [3]:
```
#1.1
#指定位置的sst
group_data=ds.sst.sel(lon=slice(120,170),lat=slice(-5,5)).groupby('time.month')
#去季节化，在三个月计算Niño 3.4，这几行求助于赵望超
anom=group_data - group_data.mean(dim='time')
resample_obj = anom.resample(time="3M")
ds_anom_resample = resample_obj.mean(dim="time")
#得到El Niño or La Niña events，np.logical_or为网上查到
masked_ds_anom_resample = ds_anom_resample.where(np.logical_or(ds_anom_resample < -0.
masked_ds_anom_resample
```

Out[3]: xarray.DataArray 'sst' (**time**: 229, **lat**: 5, **lon**: 26)

```
array([[[        nan,         nan,         nan, ..., -0.5904255 ,
         -0.51613617, -0.5157356 ],
        [        nan,         nan,         nan, ..., -0.60107803,
         -0.5806999 , -0.5200424 ],
        [        nan,         nan,         nan, ..., -0.61279106,
         -0.5868416 , -0.55138206],
        [        nan,         nan,         nan, ..., -0.5768242 ,
         -0.56368065, -0.5451031 ],
        [        nan,         nan,         nan, ...,         nan,
                 nan,         nan]],

       [[        nan,         nan,         nan, ..., -0.6501789 ,
         -0.5796814 , -0.58689374],
        [        nan,         nan,         nan, ..., -0.6904233 ,
         -0.68461037, -0.64244586],
        [        nan,         nan,         nan, ..., -0.7069289 ,
         -0.6881733 , -0.6722056 ],
        [        nan,         nan,         nan, ..., -0.64433545,
         -0.62889546, -0.6225446 ],
        [        nan,         nan,         nan, ..., -0.517519  ,
...
          0.51037025,         nan],
        [        nan,         nan,  0.7164224 , ...,         nan,
                 nan,         nan],
        [        nan,  0.5145791 ,  0.7320716 , ...,         nan,
                 nan,         nan],
        [        nan,         nan,  0.5983505 , ...,  0.5368557 ,
                 nan,         nan],
        [        nan,         nan,         nan, ...,  0.714798  ,
          0.5879669 ,         nan]],

       [[        nan,         nan,         nan, ...,  0.51263714,
                 nan,         nan],
        [        nan,  0.5078449 ,  0.57851505, ...,         nan,
                 nan,         nan],
        [ 0.5032301 ,  0.5828867 ,  0.66394806, ...,         nan,
                 nan,         nan],
        [        nan,         nan,  0.58321095, ...,         nan,
                 nan,         nan],
        [        nan,         nan,         nan, ...,  0.5236778 ,
                 nan,         nan]]], dtype=float32)
```

▼ Coordinates:

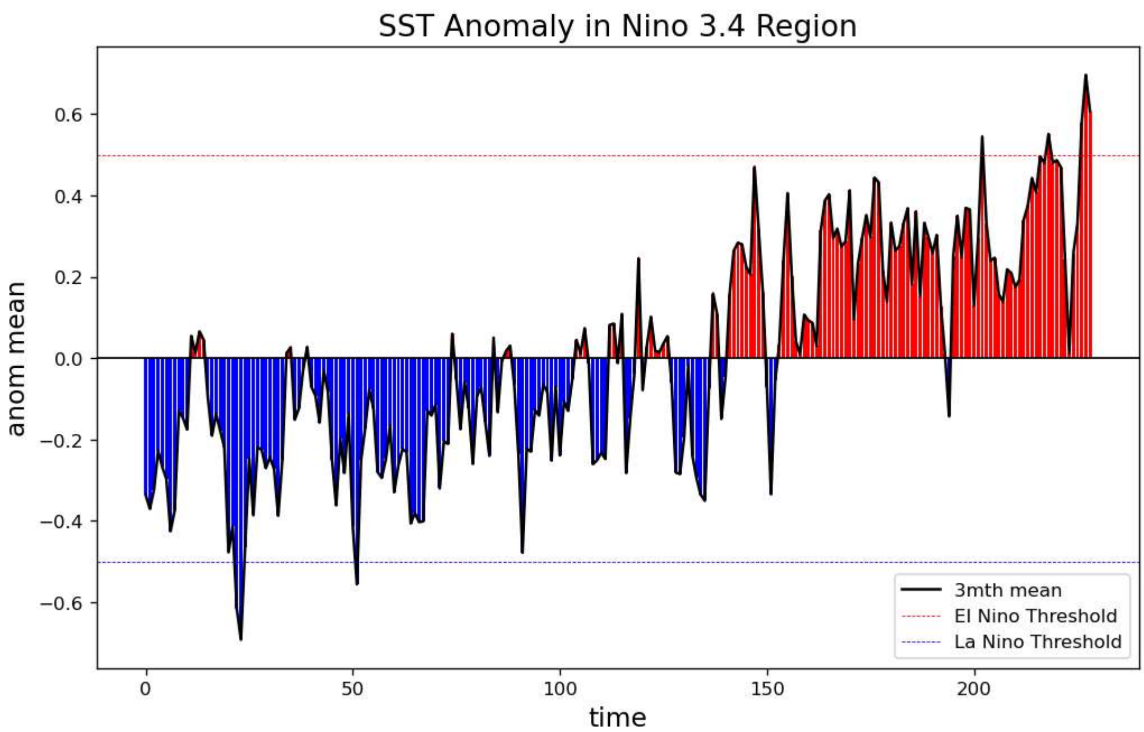
| | | | |
|---|---|---|---|
| **lat** | (lat) | float32 | -4.0 -2.0 0.0 2.0 4.0 |
| **lon** | (lon) | float32 | 120.0 122.0 124.0 ... 168.0 170.0 |
| **time** | (time) | datetime64[ns] | 1960-01-31 ... 2017-01-31 |

► Indexes: (3)

► Attributes: (0)

In [4]:
```
#1.2
ds_anom_resample_m = ds_anom_resample.mean(dim=['lat','lon'])
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)
#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','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[4]: Text(0.5, 1.0, 'SST Anomaly in Nino 3.4 Region')



In [5]:
```python
#2
dates = xr.open_dataset("CERES_EBAF-TOA_200003-201701.nc", engine="netcdf4")
dates
```

Out[5]:

xarray.Dataset

▶ Dimensions: (**lon**: 360, **time**: 203, **lat**: 180)

▼ Coordinates:

| | | | |
|---|---|---|---|
| **lon** | (lon) | float32 | 0.5 1.5 2.5 ... 357.5 358.5 ... |
| **time** | (time) | datetime64[ns] | 2000-03-15 ... 2017-01-15 |
| **lat** | (lat) | float32 | -89.5 -88.5 -87.5 ... 88.5 89.5 |

▼ Data variables:

| | | | |
|---|---|---|---|
| toa_sw_all_mon | (time, lat, lon) | float32 | ... |
| toa_lw_all_mon | (time, lat, lon) | float32 | ... |
| toa_net_all_mon | (time, lat, lon) | float32 | ... |
| toa_sw_clr_mon | (time, lat, lon) | float32 | ... |
| toa_lw_clr_mon | (time, lat, lon) | float32 | ... |
| toa_net_clr_mon | (time, lat, lon) | float32 | ... |
| toa_cre_sw_mon | (time, lat, lon) | float32 | ... |
| toa_cre_lw_mon | (time, lat, lon) | float32 | ... |
| toa_cre_net_mon | (time, lat, lon) | float32 | ... |
| solar_mon | (time, lat, lon) | float32 | ... |
| cldarea_total_d... | (time, lat, lon) | float32 | ... |
| cldpress_total_... | (time, lat, lon) | float32 | ... |
| cldtemp_total_d... | (time, lat, lon) | float32 | ... |
| cldtau_total_da... | (time, lat, lon) | float32 | ... |

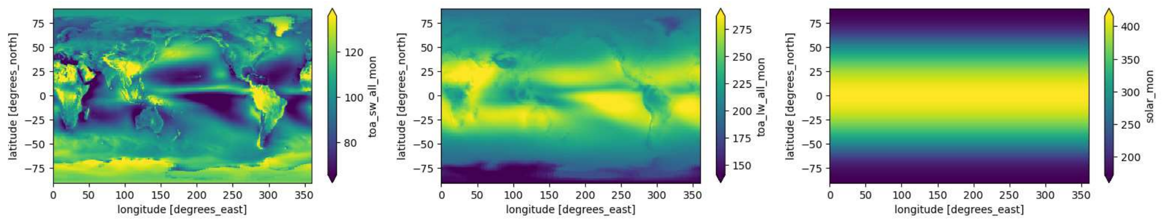
▶ Indexes: (3)

▼ Attributes:

| | |
|---|---|
| title : | CERES EBAF (Energy Balanced and Filled) TOA Fluxes. Monthly Averages and 07/2005 to 06/2015 Climatology. |
| institution : | NASA/LaRC (Langley Research Center) Hampton, Va |
| Conventions : | CF-1.4 |
| comment : | Data is from East to West and South to North. |
| Version : | Edition 4.0; Release Date March 7, 2017 |
| Fill_Value : | Fill Value is -999.0 |
| DOI : | 10.5067/TERRA+AQUA/CERES/EBAF-TOA_L3B.004.0 |
| Production_Files : | List of files used in creating the present Master netCDF file: /homedir/nloeb/ebaf/monthly_means/adj_fluxes/deliverable/sw*.gz /homedir/nloeb/ebaf/monthly_means/adj_fluxes/deliverable/lw*.gz /homedir/nloeb/ebaf/monthly_means/adj_fluxes/deliverable/net*.gz /homedir/nloeb/ebaf/monthly_means/adj_fluxes/deliverable/solflx*.gz /homedir/nloeb/ebaf/monthly_means/out_glob.dat |

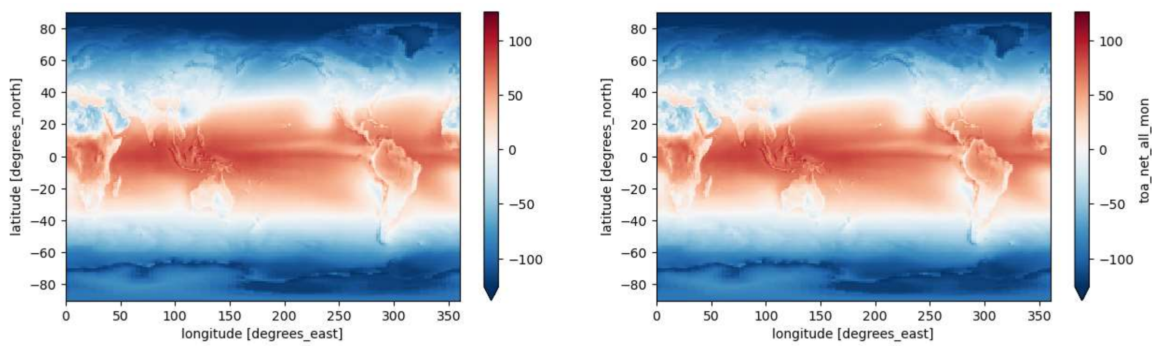
In [6]:
```
#2.1
fig,axes = plt.subplots(ncols=3, figsize=(19, 3))
dates.toa_sw_all_mon.mean(dim='time').plot(ax=axes[0], robust=True)
dates.toa_lw_all_mon.mean(dim='time').plot(ax=axes[1], robust=True)
dates.solar_mon.mean(dim='time').plot(ax=axes[2], robust=True)
```

Out[6]: <matplotlib.collections.QuadMesh at 0x2a0f584fad0>



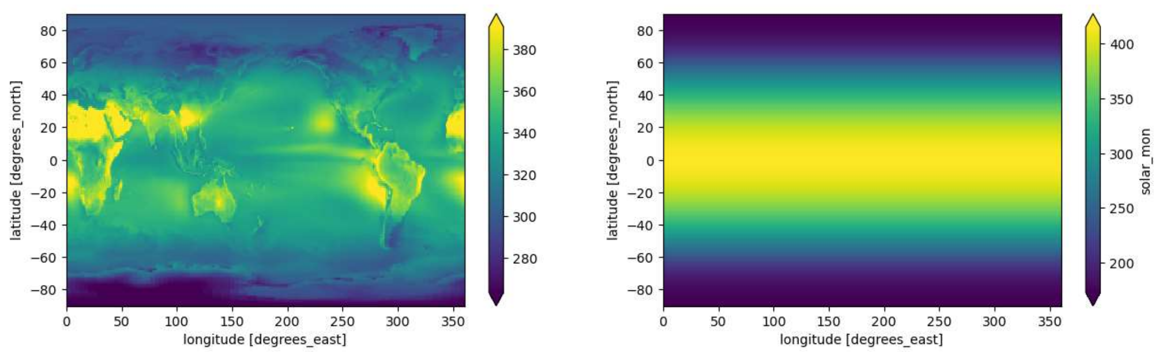

In [7]:
```
fig, axes = plt.subplots(ncols=2, figsize=(15,4))
#Incoming Solar Flux减去outgoing_longwave和outgoing_shortwave即为Net Flux
dates_total = dates.solar_mon.mean(dim='time')-dates.toa_sw_all_mon.mean(dim='time')-
dates_total.plot(ax=axes[0], robust=True)
dates.toa_net_all_mon.mean(dim='time').plot(ax=axes[1], robust=True)
```

Out[7]: <matplotlib.collections.QuadMesh at 0x2a0f56b64d0>



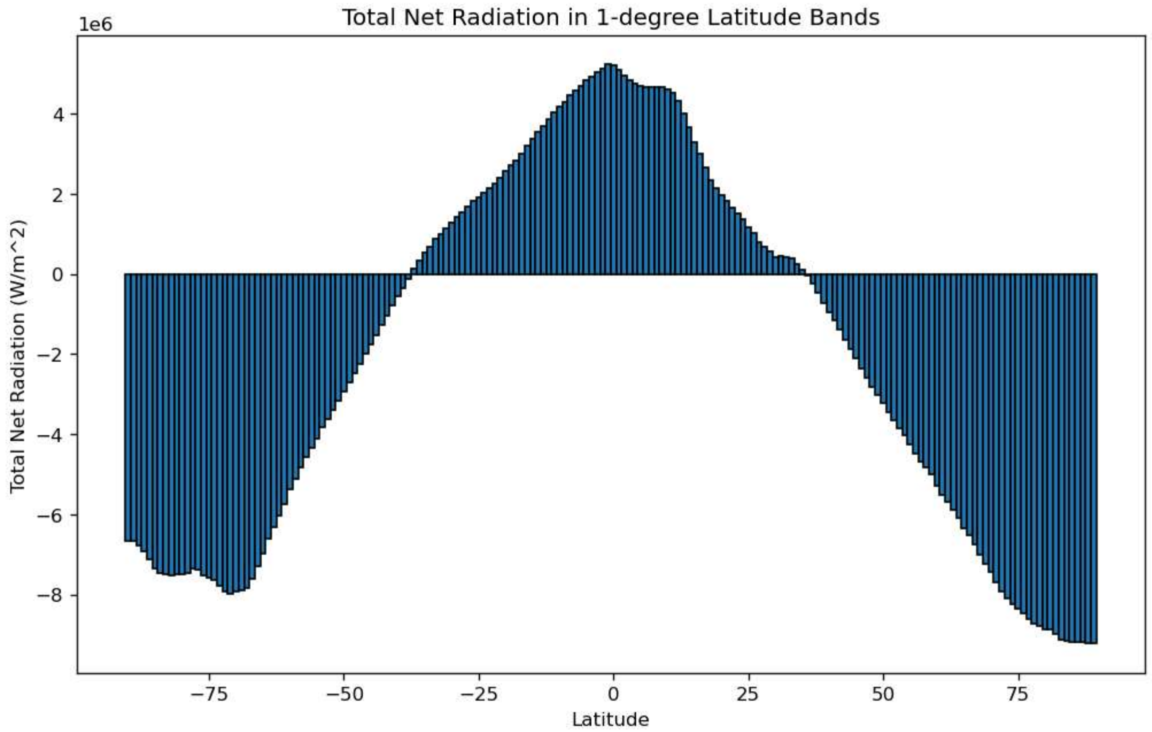

In [8]:
```
#2.2
#这一问题目没有读的很明白，感觉可能是以下两图比较相似
dates_o = dates.toa_sw_all_mon.mean(dim='time')+dates.toa_lw_all_mon.mean(dim='time')
dates_i = dates.solar_mon.mean(dim='time')
fig, axes = plt.subplots(ncols=2, figsize=(15,4))
dates_o.plot(ax=axes[0], robust=True)
dates_i.plot(ax=axes[1], robust=True)
```

Out[8]: <matplotlib.collections.QuadMesh at 0x2a0f6020e90>



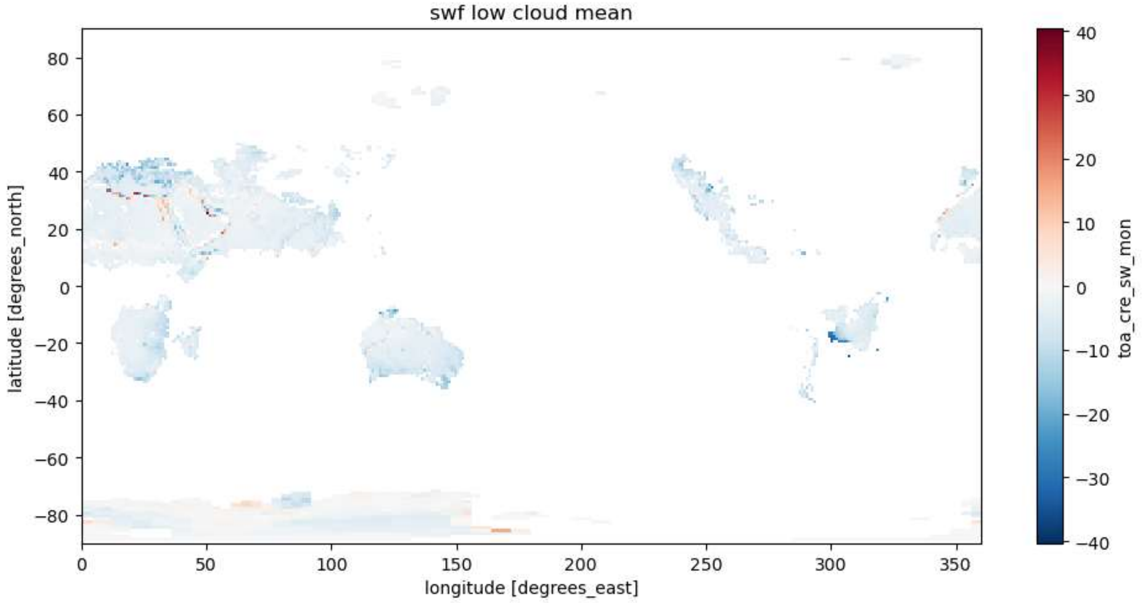
In [9]:

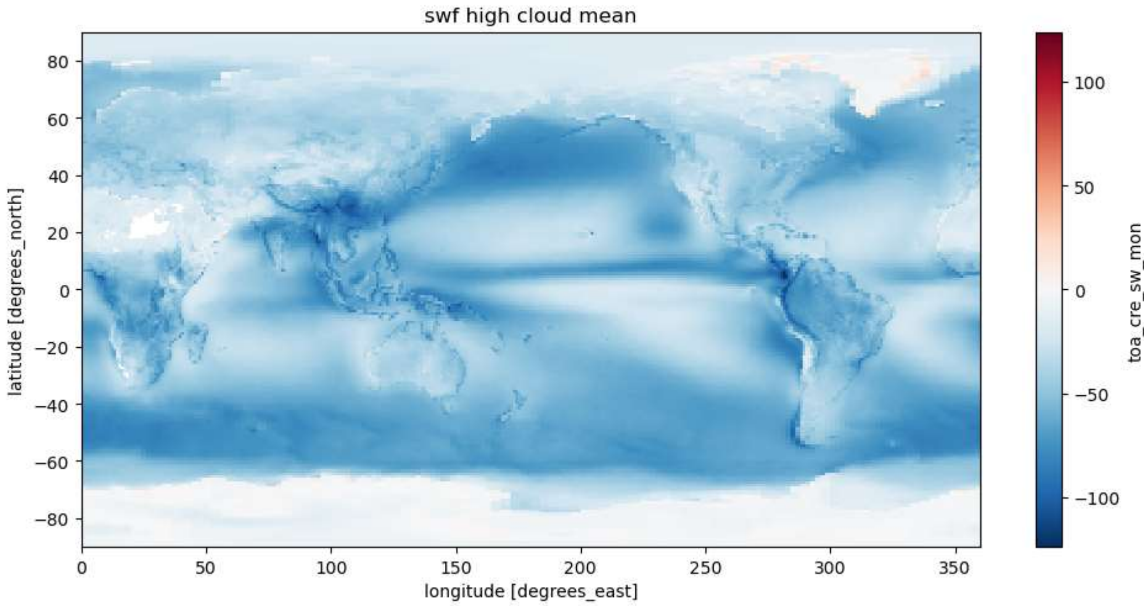
```
latitude = dates.variables['lat']
net_radiation = dates.variables['toa_net_all_mon']

# Calculate total net radiation in each 1-degree latitude band
#这里参考了龙师倩的代码
lat_bands = np.arange(-90, 91)
net_radiation_total = np.zeros(len(lat_bands) - 1)

for i in range(len(lat_bands) - 1):
    lat_1, lat_2 = lat_bands[i], lat_bands[i + 1]
    lat_mask = (latitude >= lat_1) & (latitude < lat_2)
    net_radiation_total[i] = np.sum(net_radiation[:, lat_mask])
plt.figure(figsize=(10, 6), dpi=120)
plt.bar( lat_bands[:-1],net_radiation_total, width=1, edgecolor='black')
plt.title('Total Net Radiation in 1-degree Latitude Bands')
plt.xlabel('Latitude')
plt.ylabel('Total Net Radiation (W/m^2)')
plt.show()
```

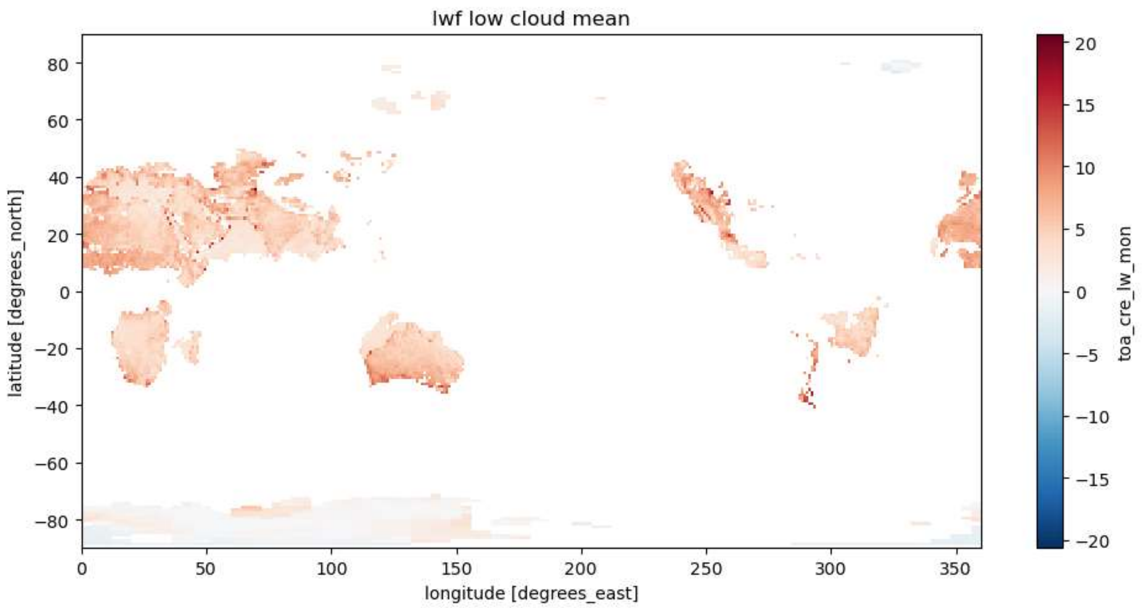


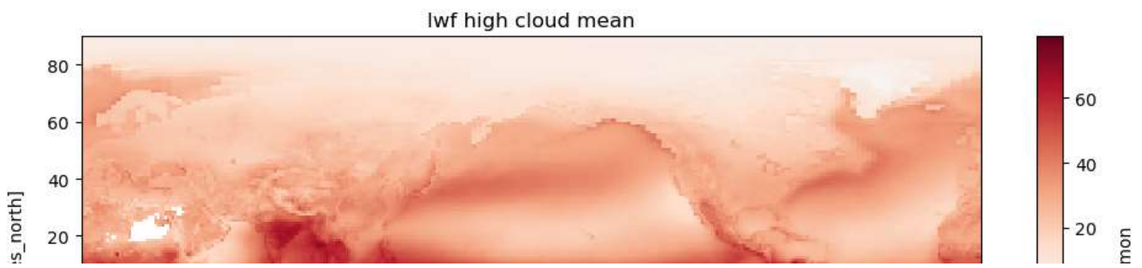
In [10]:

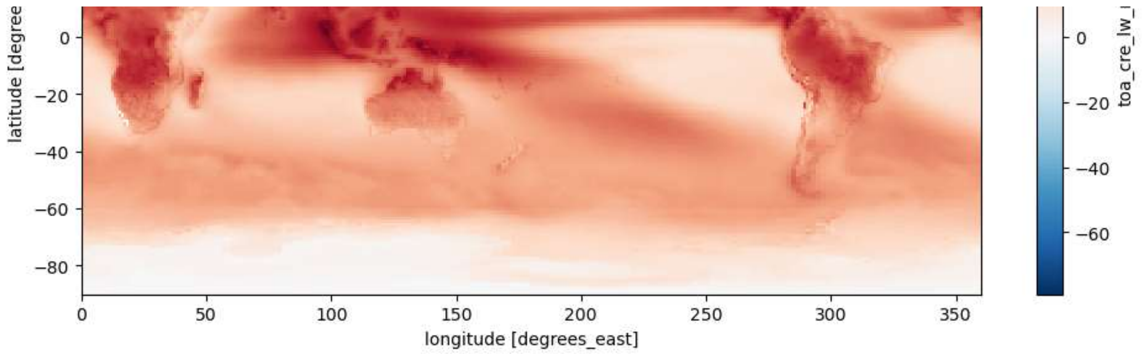
```
# 2.4
swf = dates['toa_cre_sw_mon']  # Shortwave radiation flux
lwf = dates['toa_cre_lw_mon']  # Longwave radiation flux
cld = dates['cldarea_total_daynight_mon']  # Total cloud area fraction
#计算分界值
min_value = dates['cldtau_total_day_mon'].min()
max_value = dates['cldtau_total_day_mon'].max()
range_size = max_value - min_value
low_cloud_threshold = min_value + (0.25 * range_size)
high_cloud_threshold = max_value - (0.25 * range_size)

#计算低云区和高云区的时间平均值
swf_low_cloud_mean = swf.where(cld<low_cloud_threshold).mean(dim='time')
swf_high_cloud_mean = swf.where(cld>high_cloud_threshold).mean(dim='time')
lwf_low_cloud_mean = lwf.where(cld<low_cloud_threshold).mean(dim='time')
lwf_high_cloud_mean = lwf.where(cld>high_cloud_threshold).mean(dim='time')

# Plot
fig, (ax1, ax2, ax3, ax4) = plt.subplots(4,1, figsize=(10,20))
swf_low_cloud_mean.plot(ax=ax1)
ax1.set_title('swf low cloud mean')
swf_high_cloud_mean.plot(ax=ax2)
ax2.set_title('swf high cloud mean')
lwf_low_cloud_mean.plot(ax=ax3)
ax3.set_title('lwf low cloud mean')
lwf_high_cloud_mean.plot(ax=ax4)
ax4.set_title('lwf high cloud mean')
plt.tight_layout()
plt.show()
```


swf low cloud mean
latitude [degrees_north]
longitude [degrees_east]
toa_cre_sw_mon


swf high cloud mean
latitude [degrees_north]
longitude [degrees_east]
toa_cre_sw_mon

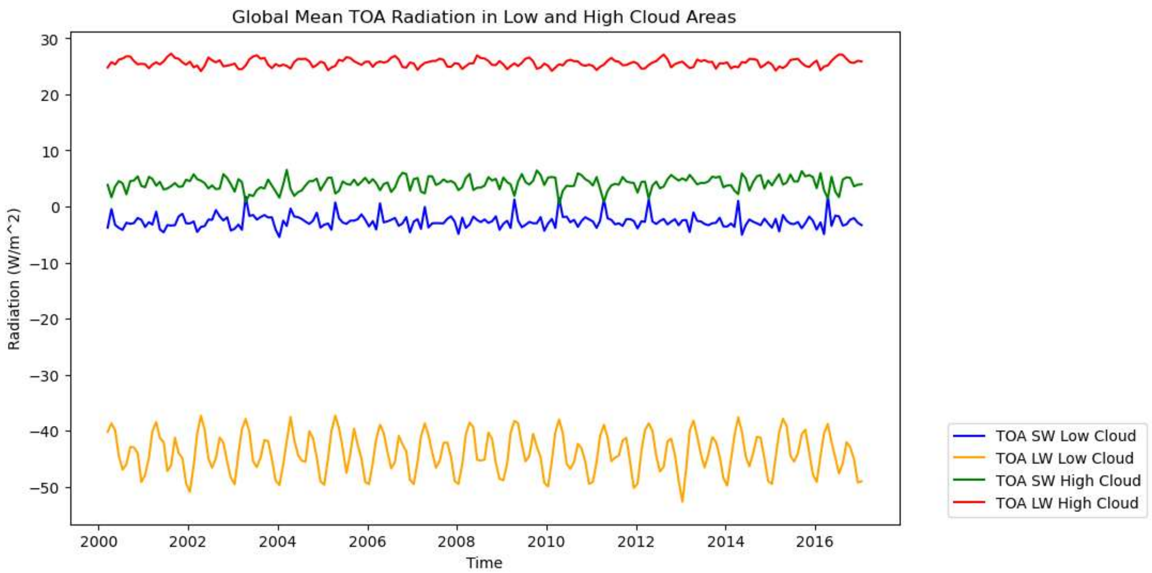

lwf low cloud mean
latitude [degrees_north]
longitude [degrees_east]
toa_cre_lw_mon


lwf high cloud mean




In [11]:

```
#2.5
#计算平均辐射
swf_low_cloud_mean_1 = swf.where(cld<low_cloud_threshold).mean(dim=['lon','lat'])
swf_high_cloud_mean_1 = swf.where(cld>high_cloud_threshold).mean(dim=['lon','lat'])
lwf_low_cloud_mean_1 = lwf.where(cld<low_cloud_threshold).mean(dim=['lon','lat'])
lwf_high_cloud_mean_1 = lwf.where(cld>high_cloud_threshold).mean(dim=['lon','lat'])

plt.figure(figsize=(10, 6))
plt.plot(swf_low_cloud_mean_1['time'], swf_low_cloud_mean_1, label='TOA SW Low Cloud'
plt.plot(swf_high_cloud_mean_1['time'], swf_high_cloud_mean_1, label='TOA LW Low Clou
plt.plot(lwf_low_cloud_mean_1['time'], lwf_low_cloud_mean_1, label='TOA SW High Cloud
plt.plot(lwf_high_cloud_mean_1['time'], lwf_high_cloud_mean_1, label='TOA LW High Clo
plt.legend(loc='lower left',bbox_to_anchor=(1.05, 0))
plt.title('Global Mean TOA Radiation in Low and High Cloud Areas')
plt.xlabel('Time')
plt.ylabel('Radiation (W/m^2)')
plt.show()
```



In [12]:
```python
#3
ds3 = xr.open_dataset("MERRA2_400.inst3_3d_chm_Nv.20200109.nc4", engine="netcdf4")
ds3
```

Out[12]:

xarray.Dataset

▶ Dimensions: (**lon**: 576, **lat**: 361, **lev**: 72, **time**: 8)

▼ Coordinates:

| | | | |
|---|---|---|---|
| **lon** | (lon) | float64 | -180.0 -179.4 ... 178.8 ... |
| **lat** | (lat) | float64 | -90.0 -89.5 -89.0 ... 89.... |
| **lev** | (lev) | float64 | 1.0 2.0 3.0 4.0 ... 70.0 ... |
| **time** | (time) | datetime64[ns] | 2020-01-09 ... 2020-01... |

▼ Data variables:

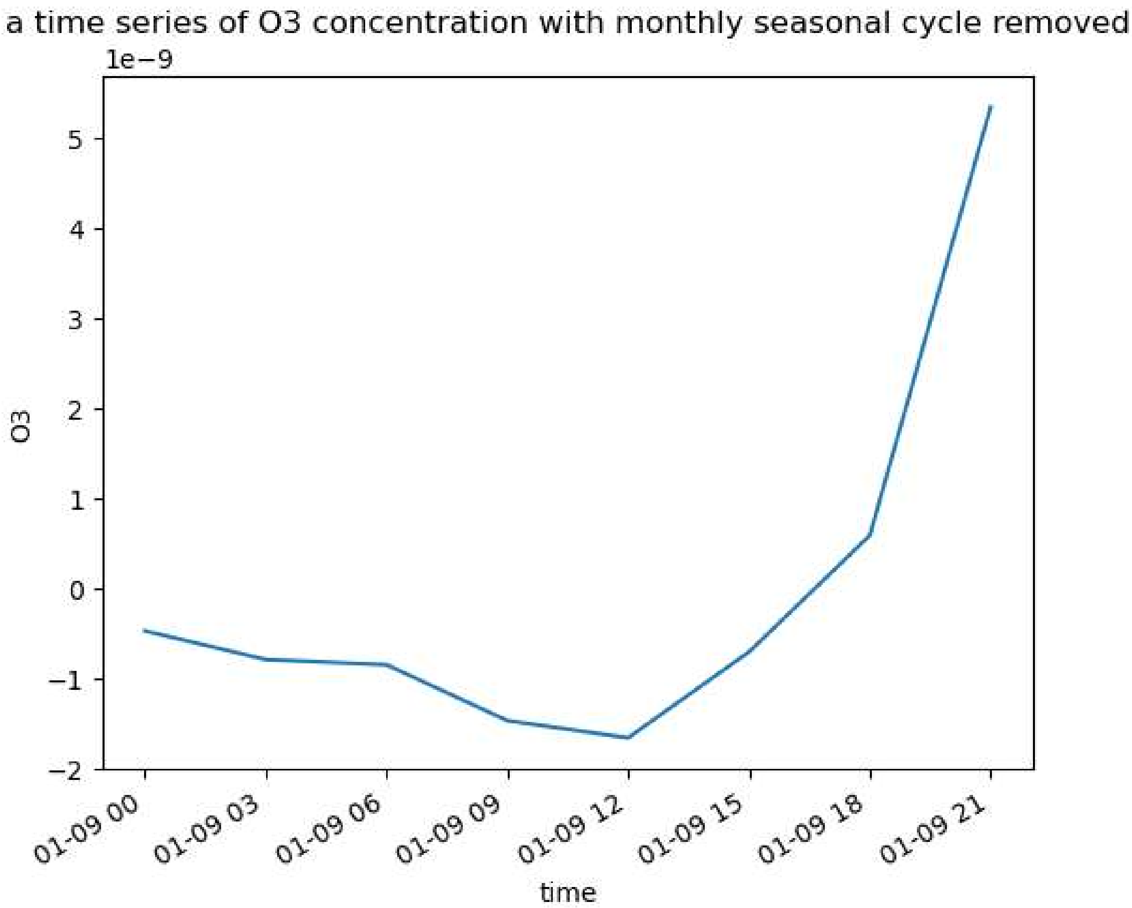
| | | | |
|---|---|---|---|
| AIRDENS | (time, lev, lat, lon) | float32 | ... |
| CO | (time, lev, lat, lon) | float32 | ... |
| DELP | (time, lev, lat, lon) | float32 | ... |
| O3 | (time, lev, lat, lon) | float32 | ... |
| PS | (time, lat, lon) | float32 | ... |

▶ Indexes: (4)

▶ Attributes: (30)

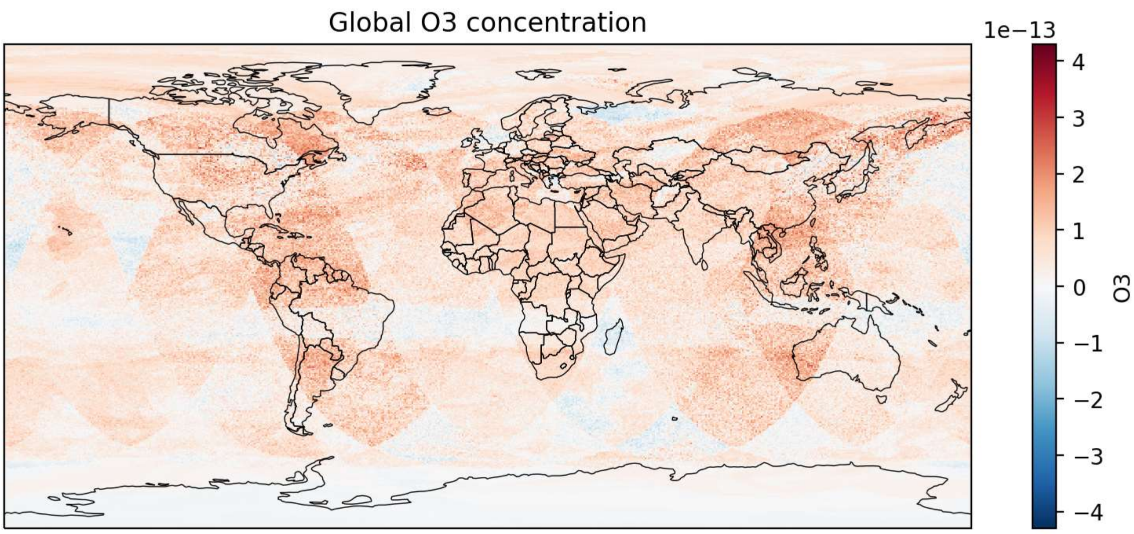
In [13]:
```
#3.1
o3 = ds3.O3.groupby('time.month')
o3_anom=o3 - o3.mean('time')
o3_anom.mean(dim=['lon','lat','lev']).plot()
plt.title('a time series of O3 concentration with monthly seasonal cycle removed')
```

Out[13]:
```
Text(0.5, 1.0, 'a time series of O3 concentration with monthly seasonal cycle remo
ved')
```



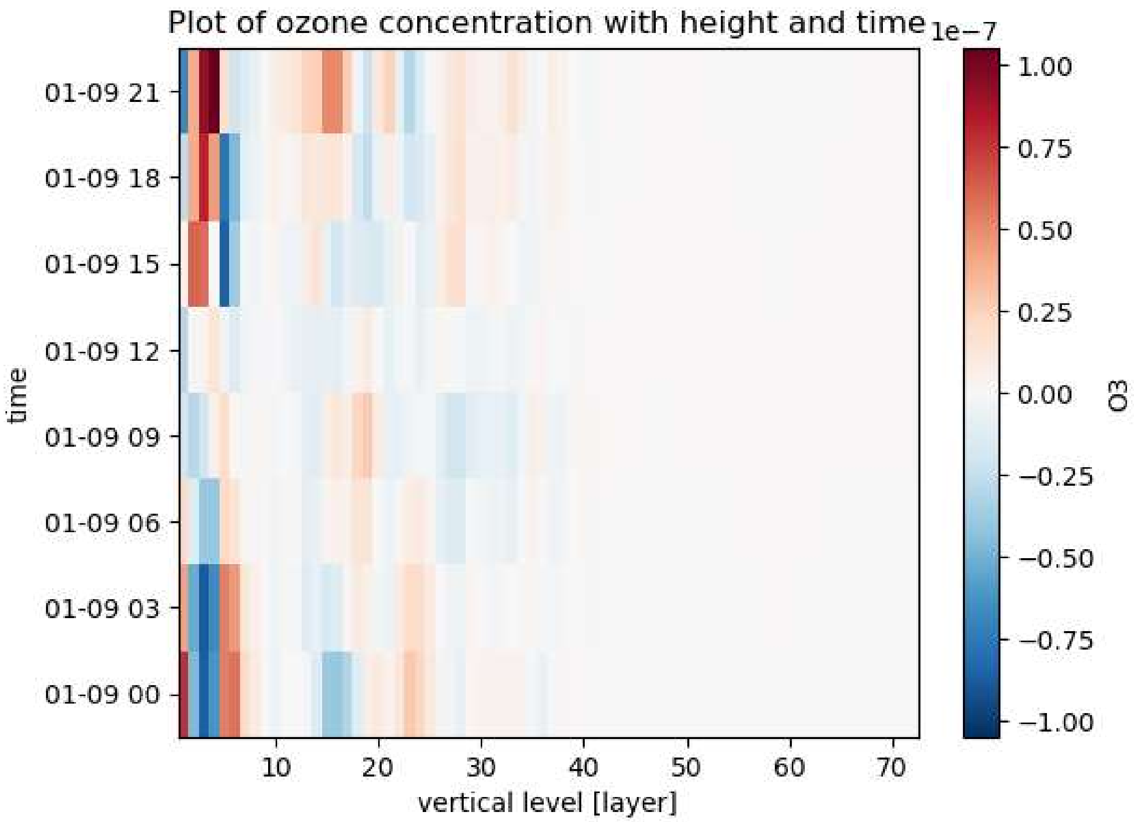
In [14]:
```
#3.2.1
plt.figure(figsize=(10,4), dpi=200)
proj = ccrs.PlateCarree()
ax    = plt.axes(projection=proj)
ax.add_feature(cfeature.NaturalEarthFeature(category='cultural',
                                            name='admin_0_countries',
                                            scale='110m',
                                            facecolor='none',
                                            edgecolor='black',
                                            linewidth=0.5))
o3_anom.mean(dim=['time','lev']).plot()
plt.title('Global O3 concentration')
#绘制全球O3浓度平均值
```

Out[14]: Text(0.5, 1.0, 'Global O3 concentration')



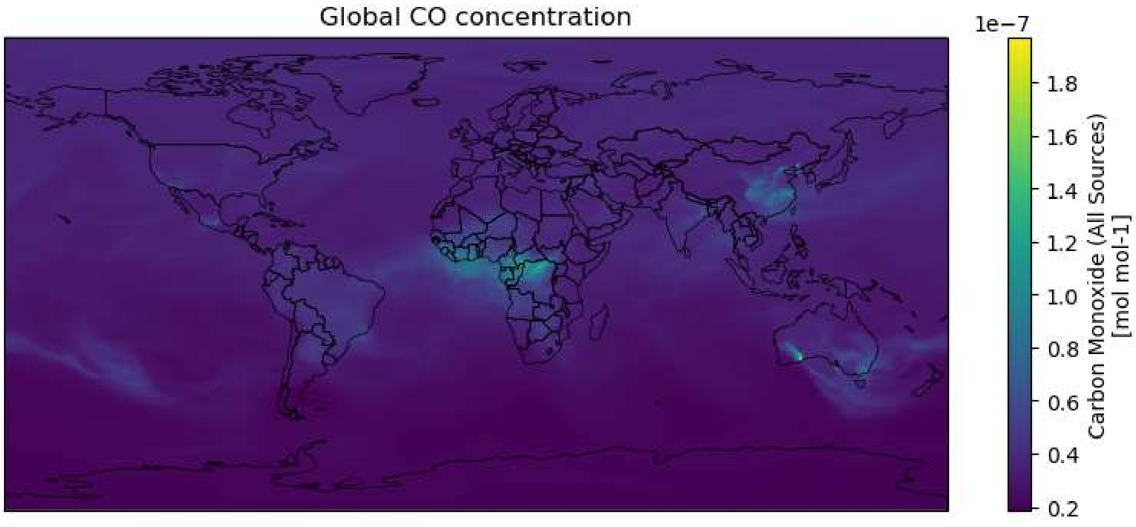
In [15]:
```
#3.2.2
o3_anom.mean(dim=['lon','lat']).plot()
plt.title('Plot of ozone concentration with height and time')
#臭氧浓度随高度和时间的关系图
```

Out[15]: Text(0.5, 1.0, 'Plot of ozone concentration with height and time')



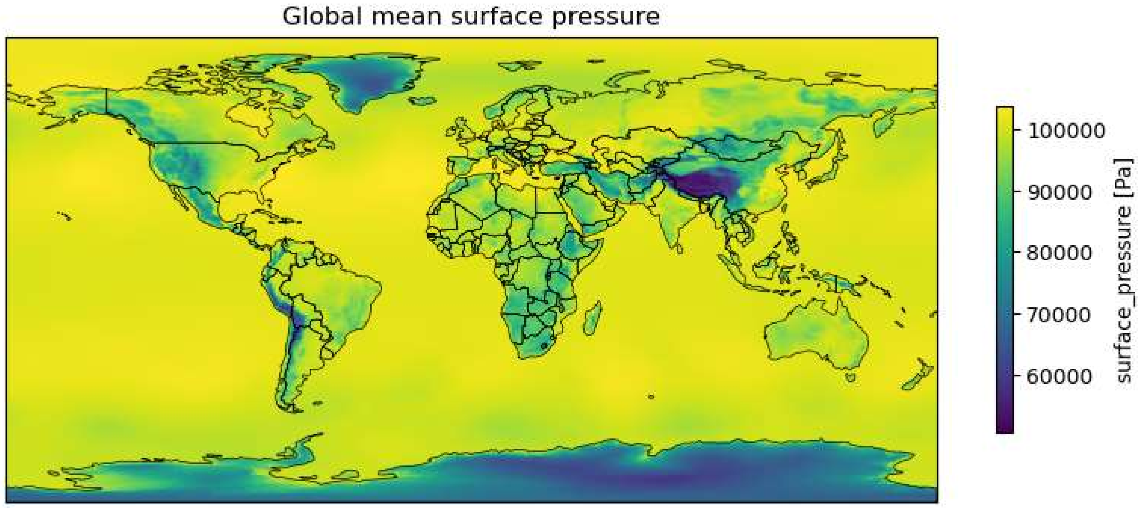
In [16]:
```
#3.2.3
#全球CO浓度
plt.figure(figsize=(10,4), dpi=100)
proj = ccrs.PlateCarree()
ax   = plt.axes(projection=proj)
ax.add_feature(cfeature.NaturalEarthFeature(category='cultural',
                                            name='admin_0_countries',
                                            scale='110m',
                                            facecolor='none',
                                            edgecolor='black',
                                            linewidth=0.5))
CO = ds3.CO.groupby('time.month')
CO.mean(dim=['time','lev']).plot()
plt.title('Global CO concentration')
```

Out[16]: Text(0.5, 1.0, 'Global CO concentration')



In [17]:
```
#3.2.4
#全球各处平均表面压力
plt.figure(figsize=(10,4), dpi=100)
proj = ccrs.PlateCarree()
ax   = plt.axes(projection=proj)
ax.add_feature(cfeature.NaturalEarthFeature(category='cultural',
                                            name='admin_0_countries',
                                            scale='110m',
                                            facecolor='none',
                                            edgecolor='black',
                                            linewidth=0.5))
PS = ds3.PS.groupby('time.month').mean(dim=['time'])
PS.plot(ax=ax, transform=ccrs.PlateCarree(),cbar_kwargs={'shrink': 0.7})
plt.title('Global mean surface pressure')
```

Out[17]: Text(0.5, 1.0, 'Global mean surface pressure')



In [18]:

```
#3.2.5
rivers_10m = cfeature.NaturalEarthFeature('physical', 'rivers_lake_centerlines', '10m
plt.figure(figsize=(5,5), dpi=100)
central_lon, central_lat = 114.06, 22.54 # Shenzhen
proj = ccrs.Orthographic(central_lon, central_lat)
ax = plt.axes(projection=proj)
extent = [central_lon-10, central_lon+10, central_lat-10, central_lat+10]
ax.set_extent(extent)
ax.add_feature(cfeature.LAKES, edgecolor='blue', facecolor='blue', zorder=2)
ax.add_feature(rivers_10m, facecolor='None', edgecolor='blue', linewidth=0.5)
ax.coastlines(resolution='10m')
ax.gridlines()
PS = ds3.PS.groupby('time.month').mean(dim=['time'])
PS.plot(ax=ax, transform=ccrs.PlateCarree(),cbar_kwargs={'shrink': 0.7})
plt.title('Surface pressure in the area around Shenzhen')
#深圳附近地区的表面气压
```

Out[18]: Text(0.5, 1.0, 'Surface pressure in the area around Shenzhen')