# 1. Global methane levels from 2002

For this problem set, methane levels have been determined by applying several algorithms to different satellite instruments. Download the netCDF4 file (200301_202006-C3S-L3_GHG-PRODUCTS-OBS4MIPS-MERGED-v4.3.nc) here, which contains monthly-averaged methane levels (xch4) in the unit of ppb at each 5° (lon) x 5° (lat) grid over the globe from 2003-01 to 2020-06.

In [1]:

```python
import netCDF4
import xarray as xr
import numpy as np
import pandas as pd
import matplotlib as mpl
import matplotlib.pyplot as plt
import matplotlib.gridspec as gridspec
import warnings
warnings.filterwarnings("ignore")     #忽略warnings
ds = xr.open_dataset("200301_202006-C3S-L3_GHG-PRODUCTS-OBS4MIPS-MERGED-v4.3.nc", engine="netcdf4")
ds
```

Out[1]:

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:

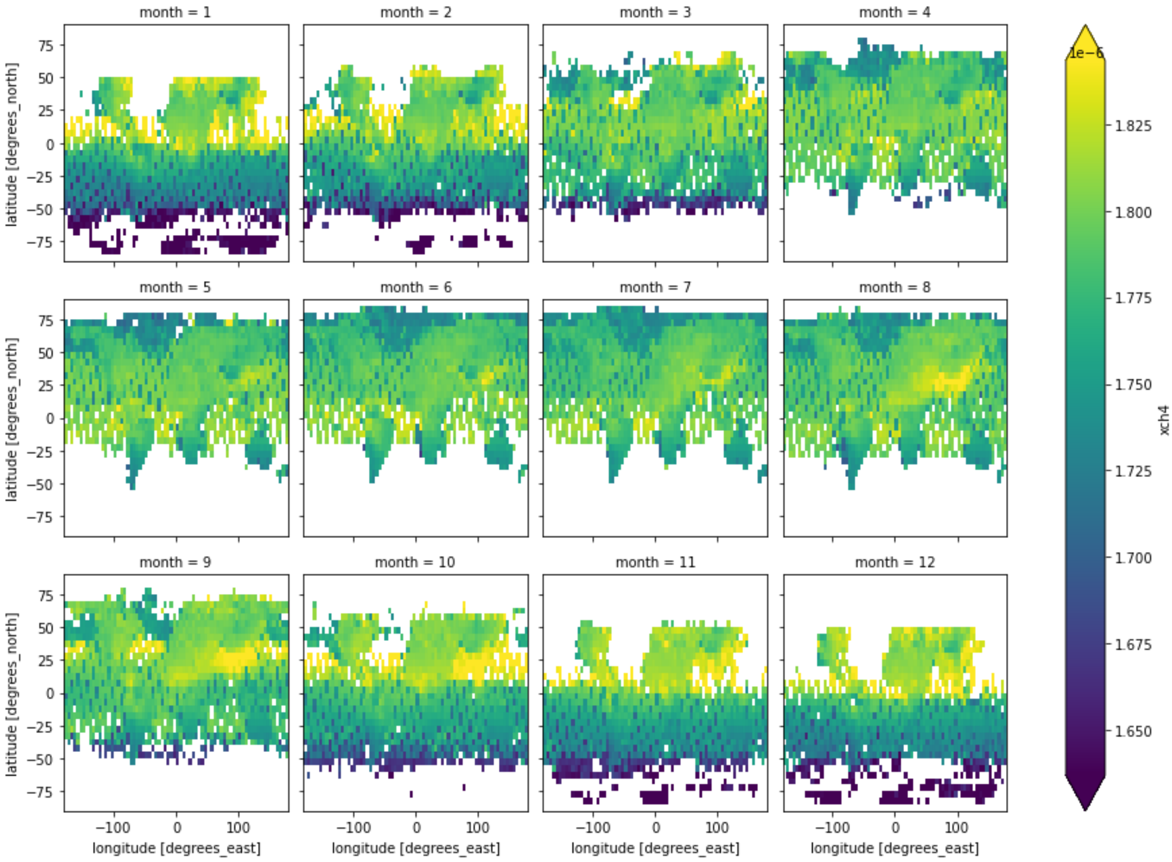
| | | | |
|---|---|---|---|
| time_bnds | (time, bnds) | datetime64[ns] | ... |
| lat_bnds | (lat, bnds) | float64 | ... |
| lon_bnds | (lon, bnds) | float64 | ... |
| pre | (pressure) | float64 | ... |
| pre_bnds | (pressure, bnds) | float64 | ... |
| land_fraction | (lat, lon) | float64 | ... |
| xch4 | (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)

**1.1 [5 points] Compute methane climatology for each month, and plot your results in 12 panels.**

In [31]:

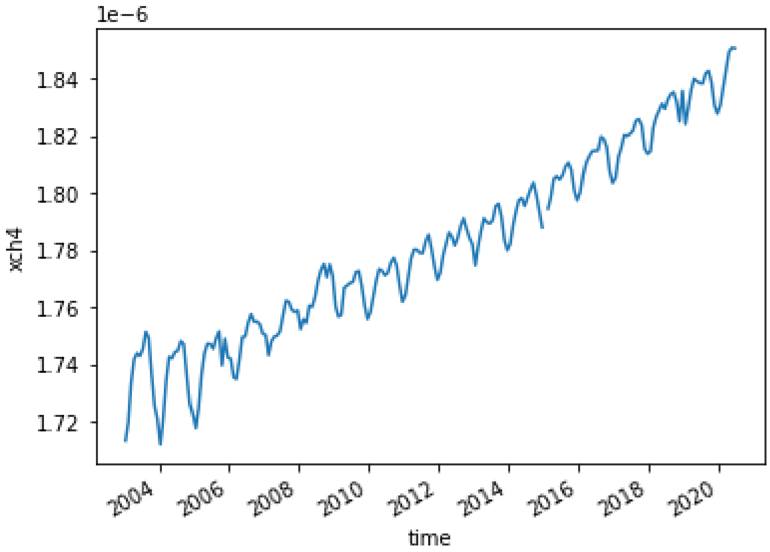
```
mc = ds.xch4
q1_1 = mc.groupby(mc.time.dt.month).mean()
q1_1.plot(col="month",    #Draw the image according to the categories of the month
          col_wrap=4,
          robust=True)  #'robust = True' to eliminate outliers
plt.show()
```




**1.2 [5 points] Plot globally-averaged methane from 2003-01 to 2020-06 as a time series. Describe your results. Check your plot with this one.**

In [30]:

```
weight = np.cos(np.deg2rad(mc.lat))
mc.weighted(weight).mean(dim=('lat','lon'),skipna=True).plot()
plt.show()
```

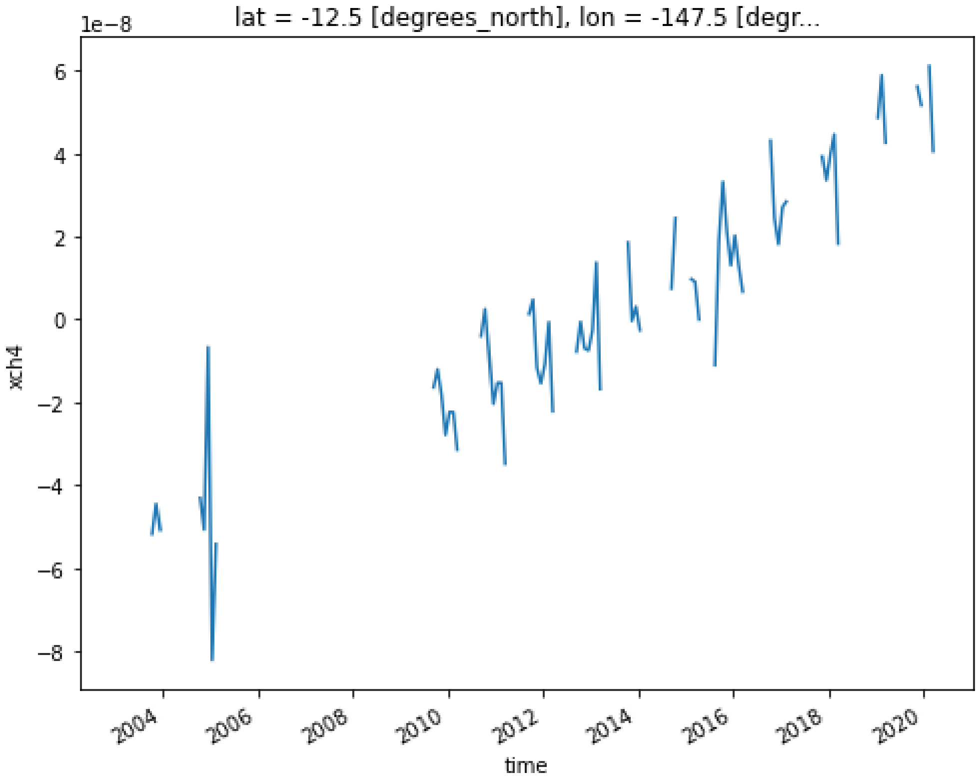



A: Globally-averaged methane climatology goes up over time, and has a distinct seasonal periodicity

**1.3 [5 points] Plot deseasonalized methane levels at point [15°S, 150°W] from 2003-01 to 2020-06 as a time series. Describe your results.**

In [29]:

```
groupdata = mc.groupby('time.month')
mc_anom = groupdata - groupdata.mean(dim='time')
mc_anom.sel(lon=-150, lat=-15,method='nearest').plot(figsize=(8, 6))
plt.show()
```




A: There will be many NANs near the point [15°S, 150°W], resulting in an incomplete graph

**2.1 [10 points] Compute monthly climatology for SST from Niño 3.4 region, and subtract climatology from SST time series to obtain anomalies.**

In [5]:

```
da = xr.open_dataset("NOAA_NCDC_ERSST_v3b_SST.nc", engine="netcdf4")
weights = np.cos(np.deg2rad(da.lat))
sst_mean = da.sst.sel(lat=slice(-5,5),
                      lon=slice(-170+360,-120+360)).weighted(weights).mean(dim=('lon','lat'))  #Wei
monthly_sst = sst_mean.groupby('time.month').mean()
anom = sst_mean.groupby("time.month")-monthly_sst # Apply mean to grouped data, and then compute the
anom_3 = anom.rolling(time = 3).mean()     # Show rolling means
mean_3_anomalies = anom_3.isel(time=slice(2, 684))   #Removing NAN
df = pd.DataFrame(mean_3_anomalies,columns=['mean_3_anomalies'])
df['date'] = pd.DataFrame(mean_3_anomalies.time)
df
```

Out[5]:

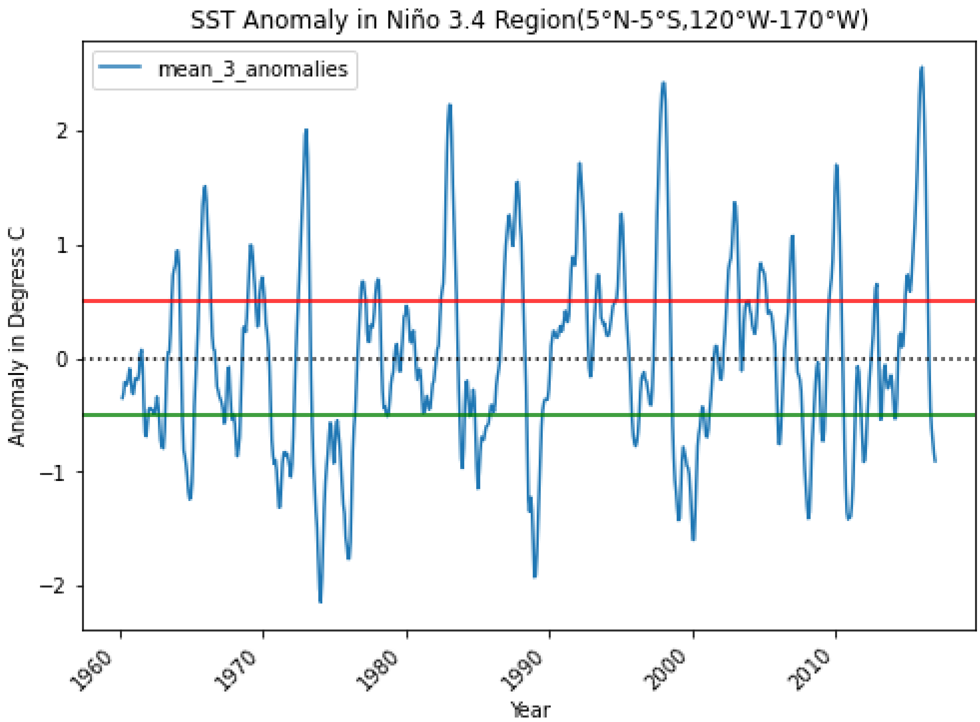
| | mean_3_anomalies | date |
|---|---|---|
| **0** | -0.352137 | 1960-03-15 |
| **1** | -0.307922 | 1960-04-15 |
| **2** | -0.210945 | 1960-05-15 |
| **3** | -0.240803 | 1960-06-15 |
| **4** | -0.225803 | 1960-07-15 |
| **...** | ... | ... |
| **677** | -0.442696 | 2016-08-15 |
| **678** | -0.618628 | 2016-09-15 |
| **679** | -0.728378 | 2016-10-15 |
| **680** | -0.836065 | 2016-11-15 |
| **681** | -0.907836 | 2016-12-15 |

682 rows × 2 columns

**2.2 [10 points] Visualize the computed Niño 3.4. Your plot should look similar to this one.**

In [6]:

```
df.plot(x="date",y="mean_3_anomalies",figsize=(8, 6))
plt.axhline(y=0.5,ls="-",c="r")  #Mark the line corresponding to the outlier
plt.axhline(y=0,ls=":",c="black")
plt.axhline(y=-0.5,ls="-",c="g")  #Mark the line corresponding to the outlier
plt.xticks(rotation=45)     #The X-axis is marked by a 45°  rotation
plt.ylabel('Anomaly in Degress C')
plt.xlabel('Year')
plt.title('SST Anomaly in Niño 3.4 Region(5° N-5° S,120° W-170° W)')
plt.show()
```

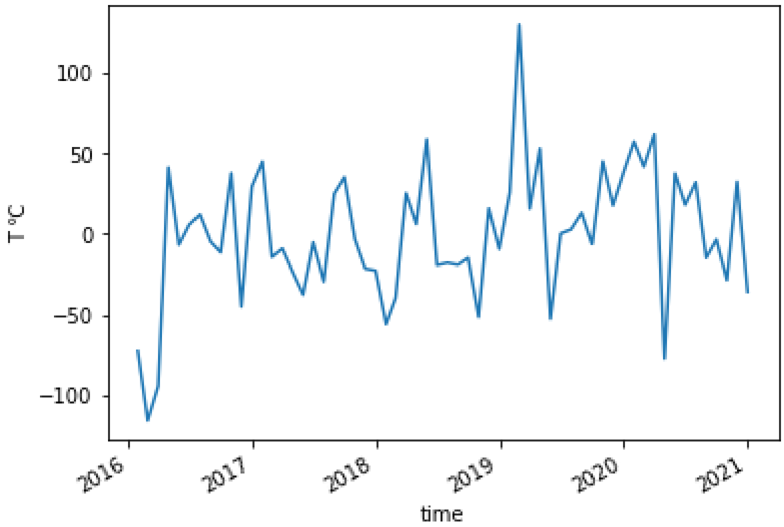



# 3. Explore a netCDF dataset

**3.1 [5 points] Plot a time series of a certain variable with monthly seasonal cycle removed.**

In [9]:

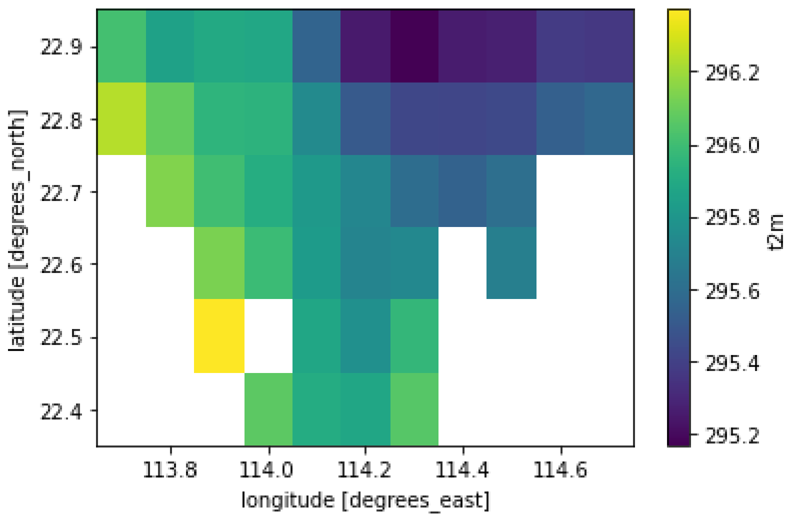
```
T = xr.open_dataset('2016-2020-T.nc',engine="netcdf4")
group_data = T.t2m.groupby('time.month')
T_anom = group_data - group_data.mean(dim='time') # Apply mean to grouped data, and then compute the
T_anom_d = T_anom.sum(dim=('latitude','longitude'))
T_anom_m = T_anom_d.resample(time='M').mean().plot()
plt.ylabel('T ℃')
plt.show()    #The original graph of the data is in 3.2
```




### 3.2 [10 points] Make at least 5 different plots using the dataset.

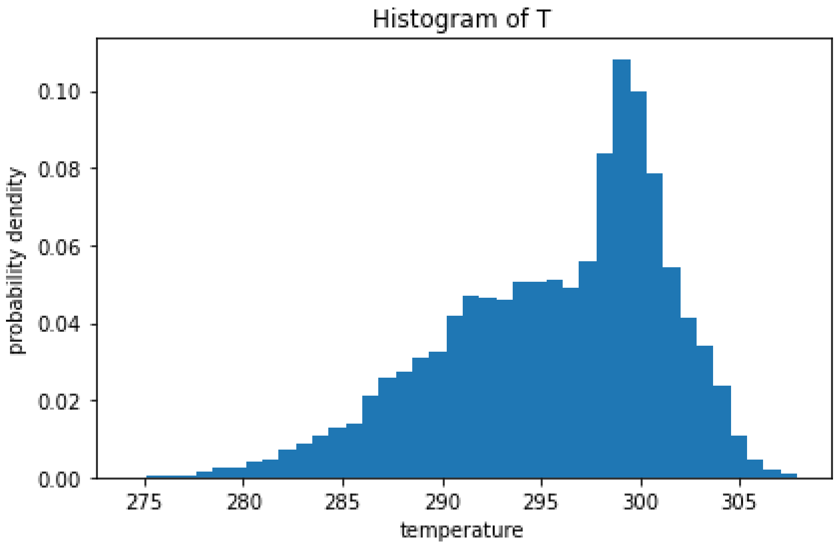
In [10]:

```
T.t2m.mean(dim='time').plot()
plt.show()
```



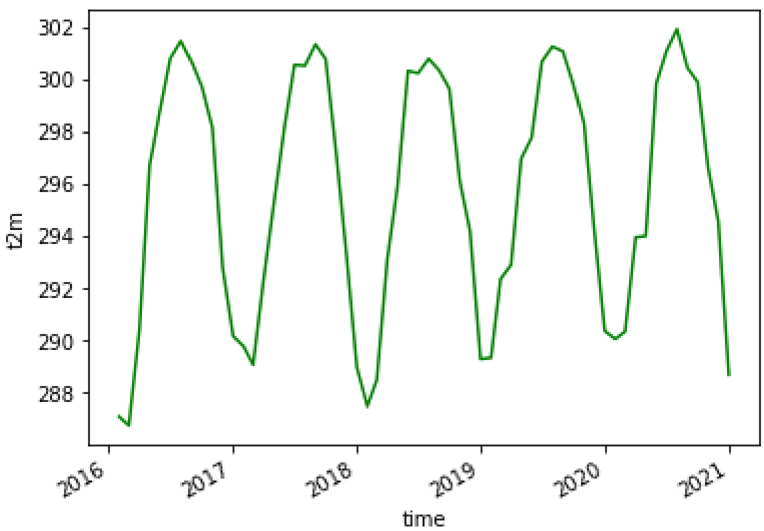
In [15]:

```
q3_2=T.t2m.mean(dim=('longitude','latitude'))    #Global data average
fig, ax = plt.subplots()
n, bins, patches = ax.hist(q3_2,40, density=1)# the histogram of the data
plt.title('Histogram of T')
plt.xlabel('temperature')
plt.ylabel('probability dendity')
plt.tight_layout()  #Automatically adjusts subgraph parameters to provide the specified population
plt.show()
```



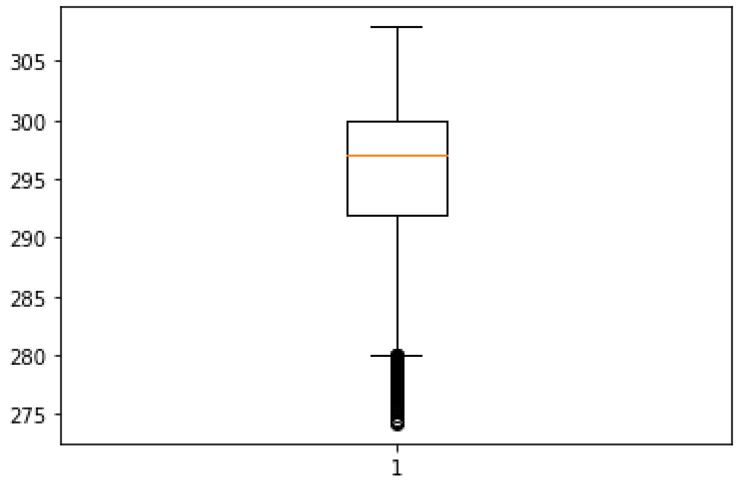

In [26]:

```
monthly_mean = q3_2.resample(time='M').mean()
monthly_mean.plot(color='g')
plt.show()
```



In [18]:

```
plt.boxplot(q3_2)
plt.show()
```




In [28]:

```
q3_2.plot()   #The original data graph shows seasonal periodicity
plt.show()
```