Assignment 03

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Due: 2022/11/15

In [1]:

```
import random
from math import *
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd
import datetime
import netCDF4
import xarray as xr
%matplotlib inline
import matplotlib.ticker as mticker
import cartopy.crs as ccrs
import cartopy.feature as cfeature
```

Ref: All the programming details were referred to the handout of course ESE5023 by professor Zhu (https://zhu-group.github.io/ese5023 (https://zhu-group.github.io/ese5023)).

1. Global methane levels from 2002

In [12]:

```
# Open a netCDF4 file
ds1 = xr.open_dataset("200301_202006-C3S-L3_GHG-PRODUCTS-OBS4MIPS-MERGED-v4.3.nc", engine="netcdf4")

# Show dataset
ds1
```

Out[12]:

xarray.Dataset

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

▼ Coordinates:

time	(time)	datetime64[ns]	2003-01-16T12:...
lat	(lat)	float64	-87.5 -82.5 -77....
lon	(lon)	float64	-177.5 -172.5 ... ...

▼ 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 [13]:

```
#单位换算，结果为ppb
ds1['xch4'] = ds1['xch4'] * 1000000000
```

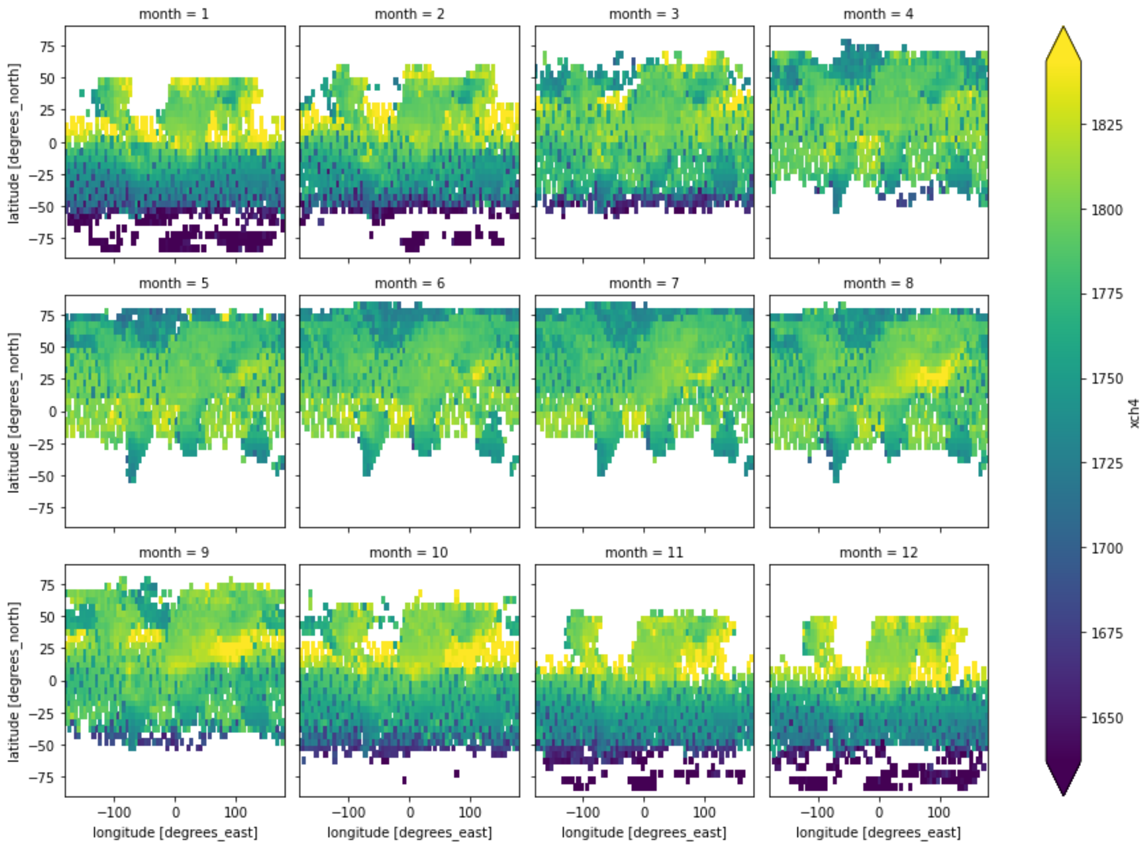
1.1

In [14]:

```
#按月度统计
xch_clim = ds1.groupby('time.month').mean()
# Plot monthly mean, one at a panel
xch_clim.xch4.plot(col="month", col_wrap=4, robust=True)
```

Out[14]:

<xarray.plot.facetgrid.FacetGrid at 0x271250e36c8>



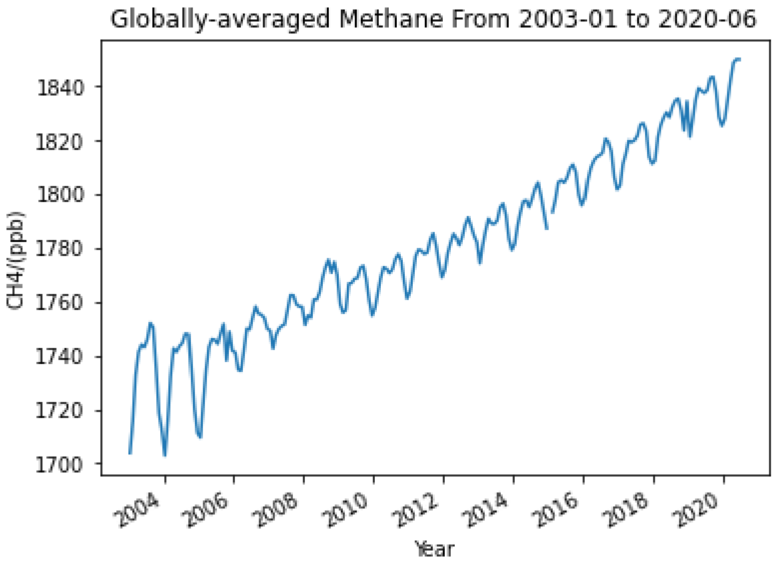
1.2

In [15]:

```
#计算全球的甲烷水平
xch_global = ds1.mean(dim=('lon','lat'))
#画出时间序列图
xch_global.xch4.plot()
plt.ylabel("CH4/(ppb)")
plt.xlabel("Year")
plt.title("Globally-averaged Methane From 2003-01 to 2020-06")
```

Out[15]:

```
Text(0.5, 1.0, 'Globally-averaged Methane From 2003-01 to 2020-06')
```

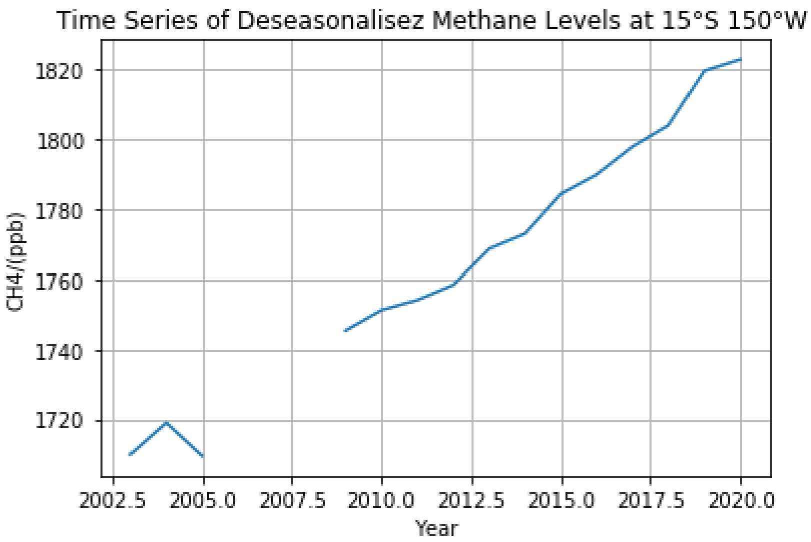


The time series diagram of globally-averagd mehtane has an increase trend as well as a obvious annual periodic fluctuation. Compared to the timeplot of global atmospheric methane by NOAA (detected on marine surface), the data used here (satellite retrieved column-average dry-air mole fraction of atmospheric methane) is little bit lower, the reason of which maybe the impact of atmosphere.

1.3

In [88]:

```
#算年平均就能够去除季节波动，同时选择指定地点画时间序列图
ds1.groupby('time.year').mean().xch4.sel(lon=-150, lat=-15, method='nearest').plot()
plt.ylabel("CH4/(ppb)")
plt.xlabel("Year")
plt.title("Time Series of Deseasonalisez Methane Levels at 15° S 150° W ")
plt.grid()
```



Some data missed from 2005 to May of 2008 at point(15°S 150°W). There is a obvious growing trend for atmospheric Methane level.

2. Niño 3.4 index

In [238]:

```
# Open a netCDF4 file
ds2 = xr.open_dataset("NOAA_NCDC_ERSST_v3b_SST.nc", engine="netcdf4")

# Show dataset
ds2
```

Out[238]:

xarray.Dataset

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

▼ Coordinates:

lat	(lat)	float32	-88.0 -86.0 -84.0 ... 86.0 8…
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	...

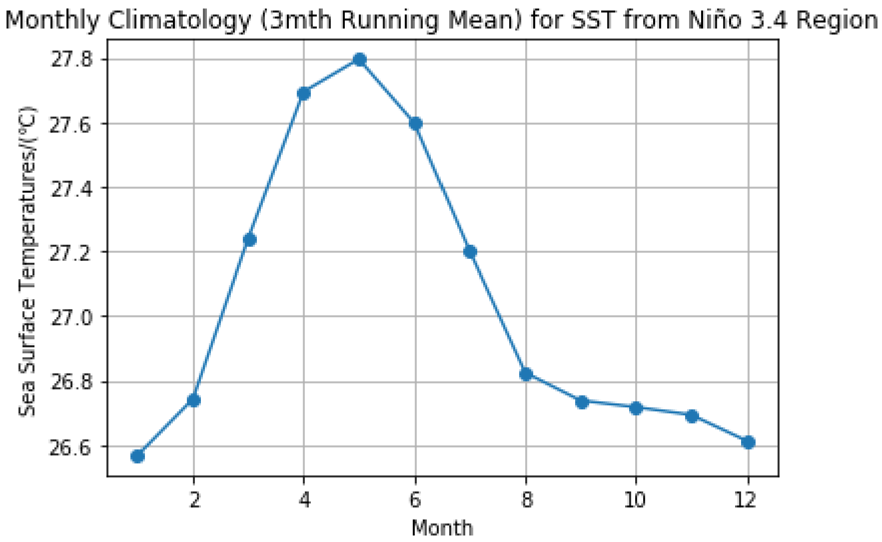
▼ Attributes:

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

2.1

In [218]:

```
#计算SST在Niño 3.4 区域的climatology，注意经度需要做一个换算
sst_clim = ds2.groupby('time.month').mean().sel(lat=slice(-5,5),lon=slice(190,240)).mean(dim=('lon','lat'))

#画出来climatology
plt.plot(sst_clim.month,sst_clim.sst,'o-')
plt.ylabel("Sea Surface Temperatures/(℃)")
plt.xlabel("Month")
plt.title("Monthly Climatology (3mth Running Mean) for SST from Niño 3.4 Region")
plt.grid()
```



In [219]:

```
#把climatology和月平均时间序列都转成dataframe
sst_clim_df = sst_clim.to_dataframe()
month_mean = ds2.sel(lat=slice(-5,5),lon=slice(190,240)).mean(dim=('lon','lat')).to_dataframe()

#都新加一列存月份
sst_clim_df['mon'] = sst_clim_df.index
month_mean['mon'] = month_mean.index.month

#合并两个df
sst_anom = month_mean.merge(sst_clim_df,on='mon')

#重命名
sst_anom.rename(columns={'sst_x':'Origin_data','sst_y':'Climatology'},inplace=True)

#增加新列计算anomalies,并展示
sst_anom['Anomalies'] = sst_anom['Origin_data'] - sst_anom['Climatology']
sst_anom['Anomalies'].head(10)
```

Out[219]:

```
0   -0.319580
1   -0.191473
2   -0.444782
3   -0.701401
4    0.851555
5   -0.782999
6    1.175951
7   -0.395283
8   -0.792450
9    0.981344
Name: Anomalies, dtype: float32
```

2.2

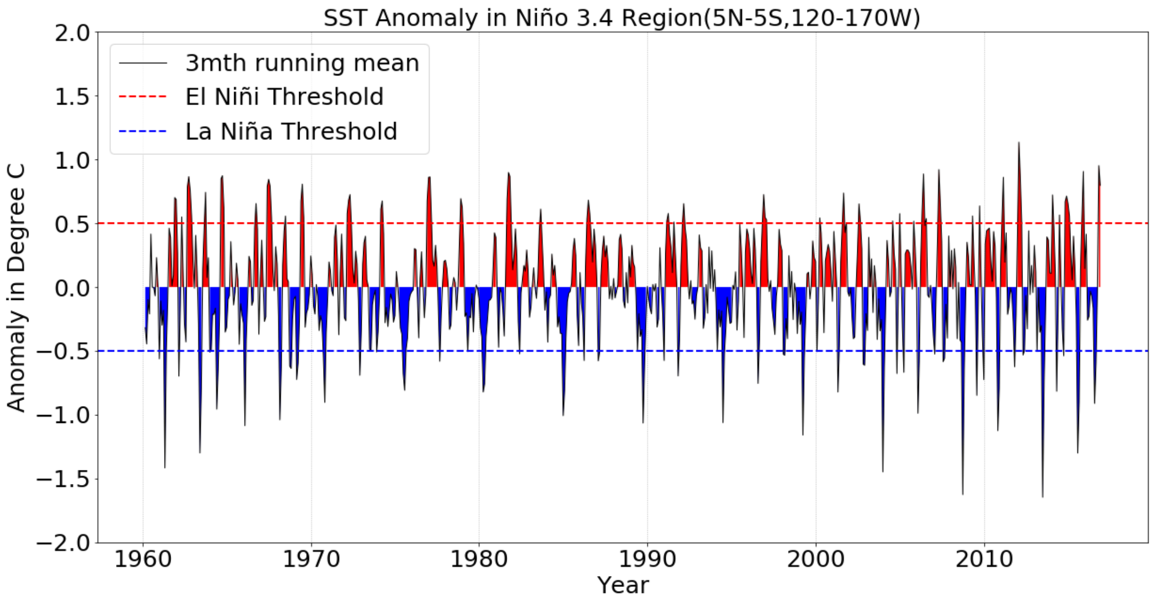
In [220]:

```
#生成新列，类型是datetime
sst_anom['Time'] = pd.date_range(start='1960-01',end='2017-01',freq='M')

#对anomaly做3month滑动平均
sst_anom['anom_3mth'] = sst_anom['Anomalies'].rolling(3,center=True).mean()
```

In [236]:

```
#画出来
fig, ax = plt.subplots(1,1,figsize=(20,10))

#画3mth 线
plt.plot(sst_anom['Time'],sst_anom['anom_3mth'],'-',lw=1,color='k',label='3mth running mean')

#大于0填充红色，小于0填充蓝色
ax.fill_between(sst_anom['Time'],sst_anom['anom_3mth'],facecolor='r',where=sst_anom['anom_3mth']
>0)
ax.fill_between(sst_anom['Time'],sst_anom['anom_3mth'],facecolor='b',where=sst_anom['anom_3mth']
<0)

#画出厄尔尼诺和拉尼娜的阈值横线
plt.axhline(0.5,color='r',ls='--',lw=2,label='El Niñi Threshold')
plt.axhline(-0.5,color='b',ls='--',lw=2,label='La Niña Threshold')

#else about plotting
plt.ylabel("Anomaly in Degree C",fontsize=25)
plt.ylim(-2,2)
plt.xlabel("Year",fontsize=25)
plt.title("SST Anomaly in Niño 3.4 Region(5N-5S,120-170W)",fontsize=25)
plt.legend(fontsize=25)
plt.tick_params(labelsize=25)
plt.grid(axis='x',ls=':')
```

```
D:\anaconda\lib\site-packages\matplotlib\cbook\__init__.py:1402: FutureWarning: Su
pport for multi-dimensional indexing (e.g. `obj[:, None]`) is deprecated and will
be removed in a future version.  Convert to a numpy array before indexing instead.
  x[:, None]
D:\anaconda\lib\site-packages\matplotlib\cbook\__init__.py:1402: FutureWarning: Su
pport for multi-dimensional indexing (e.g. `obj[:, None]`) is deprecated and will
be removed in a future version.  Convert to a numpy array before indexing instead.
  x[:, None]
D:\anaconda\lib\site-packages\matplotlib\axes\_base.py:276: FutureWarning: Support
for multi-dimensional indexing (e.g. `obj[:, None]`) is deprecated and will be rem
oved in a future version.  Convert to a numpy array before indexing instead.
  x = x[:, np.newaxis]
D:\anaconda\lib\site-packages\matplotlib\axes\_base.py:278: FutureWarning: Support
for multi-dimensional indexing (e.g. `obj[:, None]`) is deprecated and will be rem
oved in a future version.  Convert to a numpy array before indexing instead.
  y = y[:, np.newaxis]
```



Ref: The usage of function *fill()* was referred to the blog by *Soundof Silence*(https://blog.csdn.net/weixin_44521703/article/details/101995155 (https://blog.csdn.net/weixin_44521703/article/details/101995155)).

3. Explore a netCDF dataset

Data Ref:

Xie, P., and P.A. Arkin, 1997: Global precipitation: A 17-year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs. Bull. Amer. Meteor. Soc., 78, 2539 - 2558.

3.1

In [2]:

```
# Open a netCDF4 file
ds3 = xr.open_dataset("precip.mon.mean.nc", engine="netcdf4")

# Show dataset
ds3
```

Out[2]:

xarray.Dataset

▶ Dimensions: (**lat**: 72, **lon**: 144, **time**: 525)

▼ Coordinates:

lat	(lat)	float32	88.75 86.25 83.75 ... -86.2...
lon	(lon)	float32	1.25 3.75 6.25 ... 356.2 35...
time	(time)	datetime64[ns]	1979-01-01 ... 2022-09-01

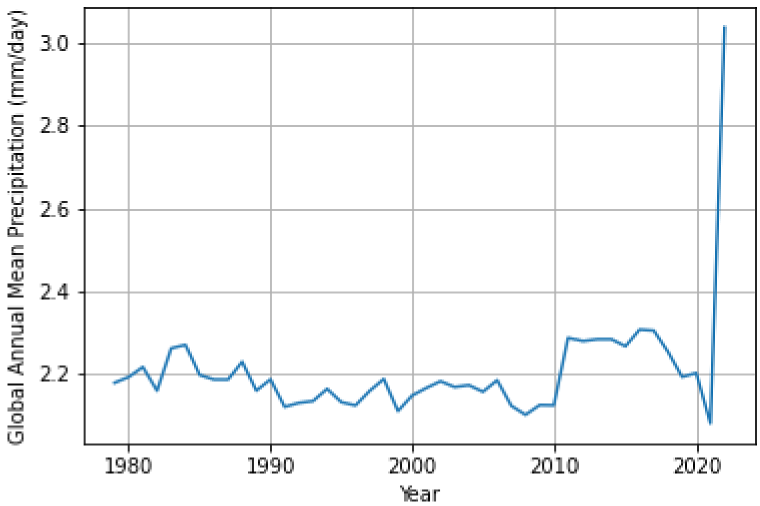
▼ Data variables:

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

▶ Attributes: (11)

In [3]:

```
ds3.mean(dim=('lon','lat')).groupby('time.year').mean().precip.plot()
plt.ylabel("Global Annual Mean Precipitation (mm/day)")
plt.xlabel("Year")
plt.grid()
```



3.2

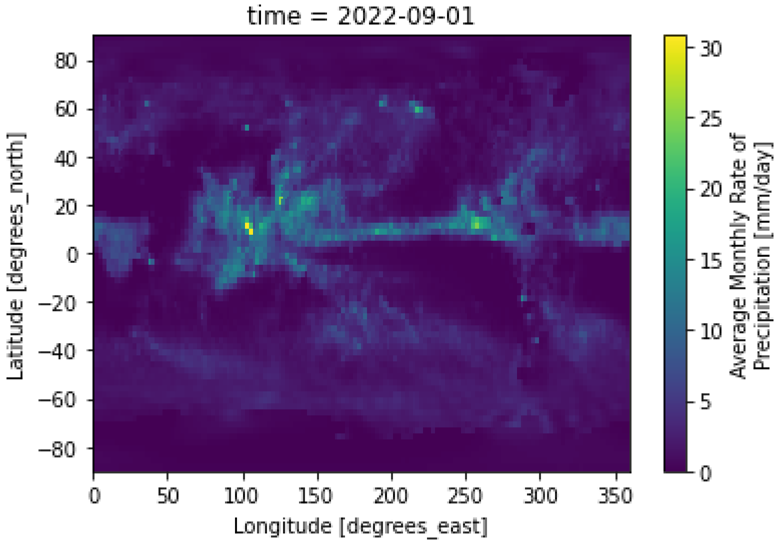
①Plot the mean precipitation in the lastest month:

In [4]:

```
# latest month [-1]
ds3.precip[-1].plot()
```

Out[4]:

```
<matplotlib.collections.QuadMesh at 0x2712436d588>
```



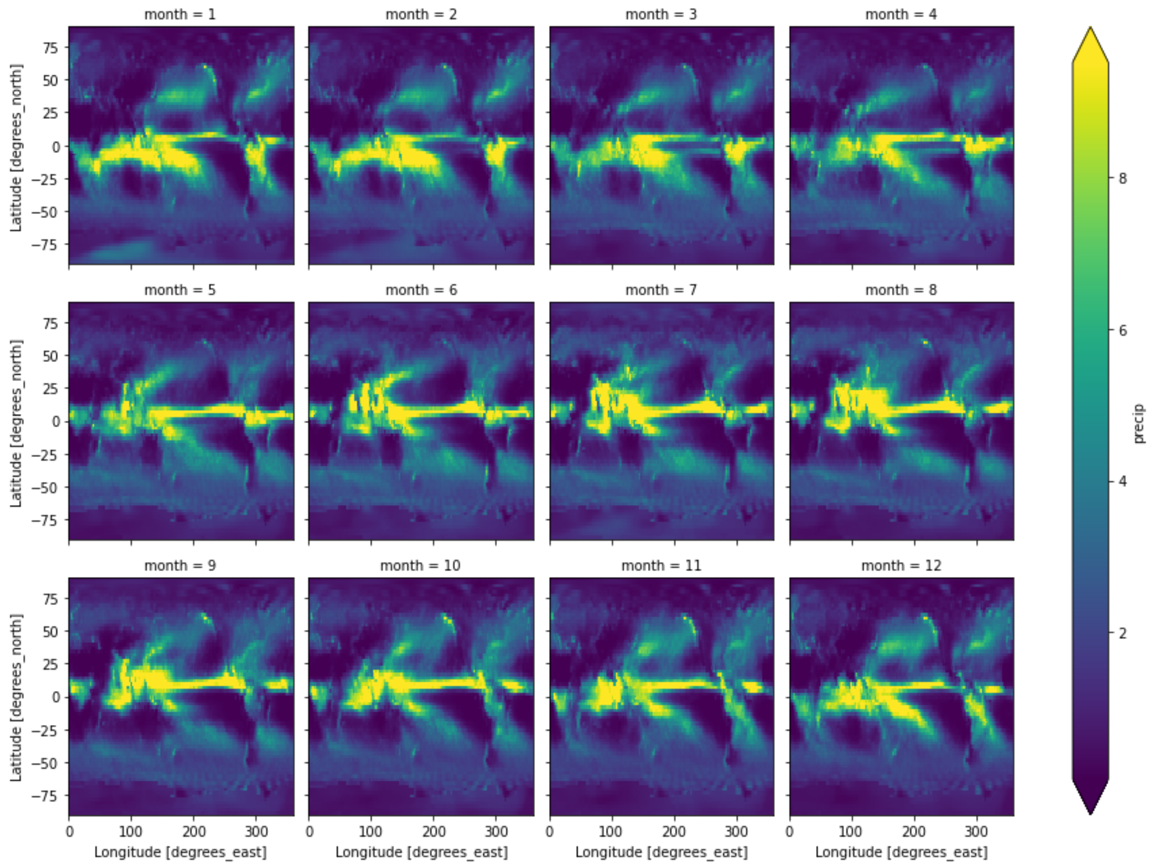
②Plot monthly climatology, one at a panel:

In [6]:

```
#按月度统计，
precip_clim = ds3.groupby('time.month').mean()

# Plot monthly mean, one at a panel
precip_clim.precip.plot(col="month", col_wrap=4, robust=True)
```

Out[6]:

<xarray.plot.facetgrid.FacetGrid at 0x27124507d88>



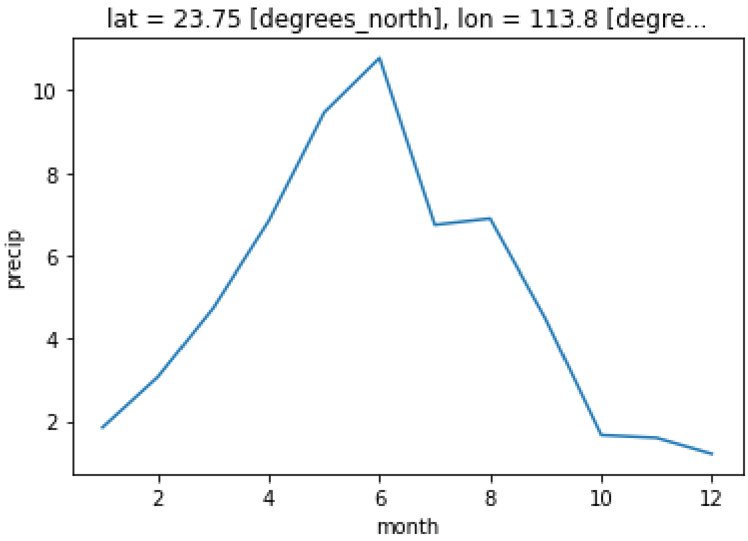
③Plot climatology in Shenzhen:

In [8]:

```
# a specific point (South China Sea)
precip_clim.sel(lon=114.03, lat=22.54, method='nearest').precip.plot()
```

Out[8]:

```
[<matplotlib.lines.Line2D at 0x27124b92b88>]
```



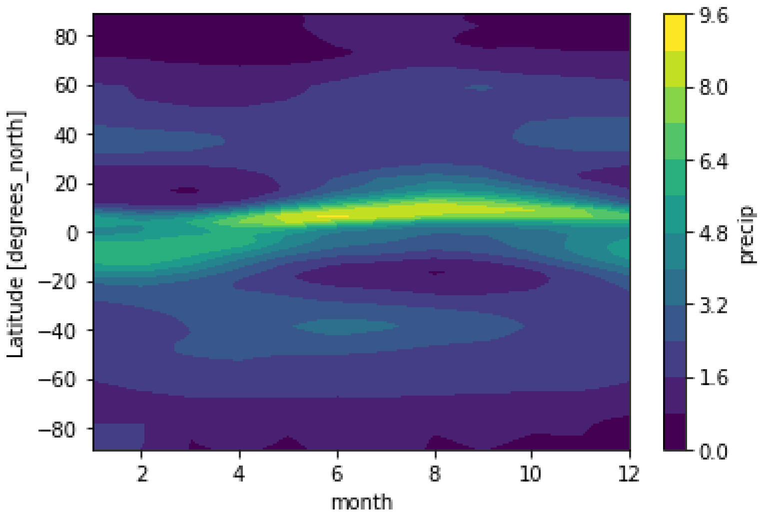
④ Plot the zonal mean climatology:

In [11]:

```
precip_clim.precip.mean(dim='lon').plot.contourf(x='month',levels=12)
```

Out[11]:

```
<matplotlib.contour.QuadContourSet at 0x27125010d48>
```



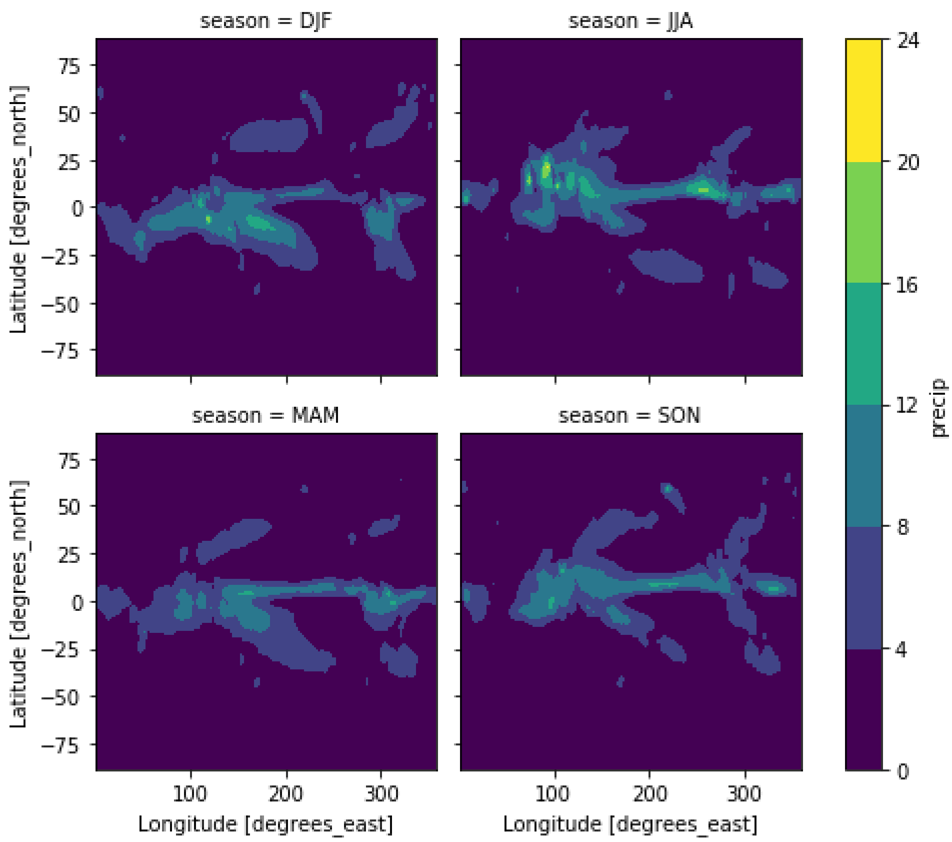
⑤Plot the seasonal climatology, one at a panel.

In [12]:

```
#按季度统计，
precip_clim2 = ds3.groupby('time.season').mean(dim='time')

# Plot monthly mean, one at a panel
precip_clim2.precip.plot.contourf(col="season", col_wrap=2)
```

Out[12]:

```
<xarray.plot.facetgrid.FacetGrid at 0x1ce133e0ec8>
```



⑥Plot the precipitation data onto the earth, and define its projection together with ocean mask.

In [24]:

```
# Create and define the size of a figure object
plt.figure(figsize=(5,5), dpi=100)

# Create an axes with Orthographic projection style
central_lon, central_lat = 114.06, 22.54 # Shenzhen
proj = ccrs.Orthographic(central_lon, central_lat)
ax = plt.axes(projection=proj)

# Plot the surface temperature
precip_clim.precip.sel(month=8).plot(ax=ax, transform=ccrs.PlateCarree(),
         cbar_kwargs={'shrink': 0.4})



# Add lat/lon gridlines, draw gridlines
gl = ax.gridlines(crs=ccrs.PlateCarree(), linewidth=0.5, color='black', alpha=0.5)

# Manipulate latitude and longitude gridline numbers and spacing
gl.ylocator = mticker.FixedLocator(np.arange(-90,91,30))
gl.xlocator = mticker.FixedLocator(np.arange(-180, 181, 30))

# Mask ocean data by adding ocean feature and changing its zorder
ax.add_feature(cfeature.OCEAN, zorder=1)
plt.title("Applying ocean mask on the precipitation data")
```

Out[24]:

```
Text(0.5, 1.0, 'Applying ocean mask on the precipitation data')
```