EES405 Assignment 1 (ms18133)

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February 21, 2023

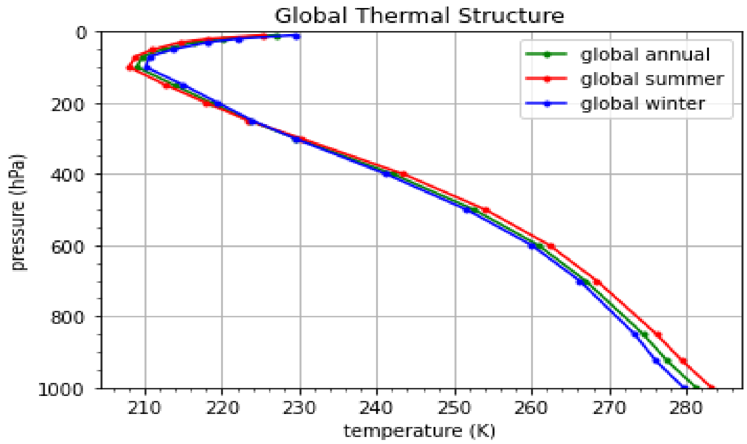
[1]: Data: NCEP/NCAR Long Term Mean Monthly Air Temperature on Pressure levels

```
# que1
import numpy as np
import cartopy as cp
import xarray as xar
import matplotlib.pyplot as plt
import statistics as stat

data1 =xar.open_dataset("/Users/RimJhim/desktop/q1 a1/air.mon.ltm.nc")
globalannual=data1.air.mean(['lat','lon','time'])
level=data1.air.level
# plt.plot(globalannual,level,'g.-',label='global annual')
# plt.title('Global Annual thermal structure')

data2=xar.open_dataset("/Users/RimJhim/desktop/q1 a1/global.jjas.nc")
globaljjas=data2.air.mean(['lat','lon','time'])
level=data2.air.level
# plt.plot(globaljjas,level,'r.-',label='global summer')
# plt.title('Global Summer Vertical thermal structure')

data3=xar.open_dataset("/Users/RimJhim/desktop/q1 a1/global.djf.nc")
globaldjf=data3.air.mean(['lat','lon','time'])
level=data3.air.level
# plt.plot(globaldjf,level,'b.-',label='global annual')
# plt.title('Global Winter Vertical thermal structure')

plt.plot(globalannual,level,'g.-',label='global annual')
plt.plot(globaljjas,level,'r.-',label='global summer')
plt.plot(globaldjf,level,'b.-',label='global winter')
plt.title('Global Thermal Structure')
plt.ylim(1000,0)
plt.xlabel("temperature (K)")
plt.ylabel('pressure (hPa)')
plt.minorticks_on()
plt.legend()
plt.grid(True)
plt.show()
```

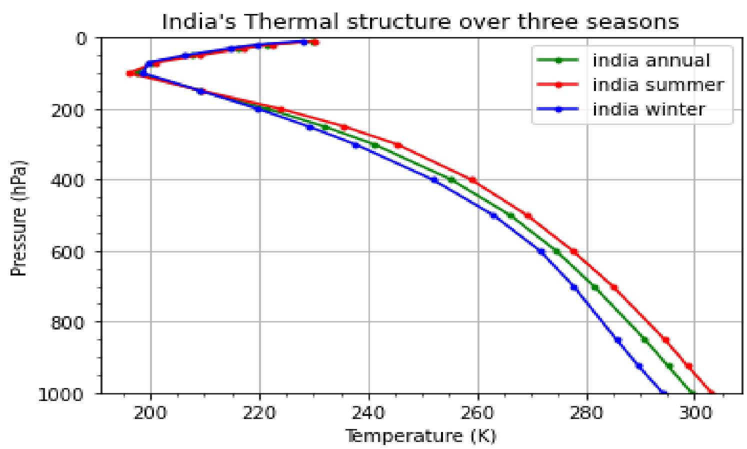
```python
data4=xar.open_dataset("/Users/RimJhim/desktop/q1 a1/airdata/india.annual.nc")
indiannual=data4.air.mean(['lat','lon','time'])
level=data4.air.level
# plt.plot(indiannual,level,'g.-',label='india annual')
# plt.title('India Annual thermal structure')

data5=xar.open_dataset("/Users/RimJhim/desktop/q1 a1/airdata/india.jjas.nc")
indsum=data5.air.mean(['lat','lon','time'])
level=data5.air.level
# plt.plot(indsum,level,'r.-',label='india summer')
# plt.title('India Summer thermal structure')

data6=xar.open_dataset("/Users/RimJhim/desktop/q1 a1/airdata/india.djf.nc")
indwin=data6.air.mean(['lat','lon','time'])
level=data6.air.level
# plt.plot(indwin,level,'b.-',label='india winter')
# plt.title('India Summer thermal structure')

plt.plot(indiannual,level,'g.-',label='india annual')
plt.plot(indsum,level,'r.-',label='india summer')
plt.plot(indwin,level,'b.-',label='india winter')
plt.ylim(1000,0)
plt.title("India's Thermal structure over three seasons")
plt.xlabel("Temperature (K)")
plt.ylabel('Pressure (hPa)')
plt.minorticks_on()
plt.legend()
plt.grid(True)
plt.show()

data7=xar.open_dataset("/Users/RimJhim/desktop/q1 a1/airdata/npol.annual.nc")
polannual=data7.air.mean(['lat','lon','time'])
level=data7.air.level
# plt.plot(polannual,level,'g.-',label='North Pole Annual')
# plt.title('North Pole Annual thermal structure')

data8=xar.open_dataset("/Users/RimJhim/desktop/q1 a1/airdata/npol.jjs.nc")
polsum=data8.air.mean(['lat','lon','time'])
level=data8.air.level
# plt.plot(polsum,level,'r.-',label='North Pole Summer')
# plt.title('North Pole Summer thermal structure')

data9=xar.open_dataset("/Users/RimJhim/desktop/q1 a1/airdata/npol.djf.nc")
polwin=data9.air.mean(['lat','lon','time'])
level=data9.air.level
# plt.plot(polwin,level,'b.-',label='North Pole Winter')
```

```python
# plt.title('North Pole Winter thermal structure')

plt.plot(polannual,level,'g.-',label='North Pole Annual')
plt.plot(polsum,level,'r.-',label='North Pole Summer')
plt.plot(polwin,level,'b.-',label='North Pole Winter')
plt.ylim(1000,0)
plt.title("Thermal structure at North Pole over three seasons")
plt.xlabel("Temperature (K)")
plt.ylabel('Pressure (hPa)')
plt.minorticks_on()
plt.legend()
plt.grid(True)
plt.show()

data10=xar.open_dataset("/Users/RimJhim/desktop/q1 a1/airdata/tropics.annual.nc")
troannual=data10.air.mean(['lat','lon','time'])
level=data10.air.level
# plt.plot(troannual,level,'g.-',label='Tropics Annual')
# plt.title('Tropics Annual thermal structure')

data11=xar.open_dataset("/Users/RimJhim/desktop/q1 a1/airdata/tropics.jjas.nc")
trosum=data11.air.mean(['lat','lon','time'])
level=data11.air.level
# plt.plot(trosum,level,'r.-',label='Tropics Summer')
# plt.title('Tropics Summer thermal structure')

data12=xar.open_dataset("/Users/RimJhim/desktop/q1 a1/airdata/tropics.djf.nc")
trowin=data12.air.mean(['lat','lon','time'])
level=data12.air.level
# plt.plot(trowin,level,'b.-',label='Tropics Winter')
# plt.title('Tropics Winter thermal structure')

plt.plot(troannual,level,'g.-',label='Tropics Annual')
plt.plot(trosum,level,'r.-',label='Tropics Summer')
plt.plot(trowin,level,'b.-',label='Tropics Winter')
plt.ylim(1000,0)
plt.title("Thermal structure at Tropics over three seasons")
plt.xlabel("Temperature (K)")
plt.ylabel('Pressure (hPa)')
plt.minorticks_on()
plt.grid(True)
plt.legend()
plt.show()

plt.plot(globaljjas,level,'y.-',label='Global summer')
plt.plot(indsum,level,'m.-',label='India')
plt.plot(polsum,level,'c.-',label='North Pole')
```

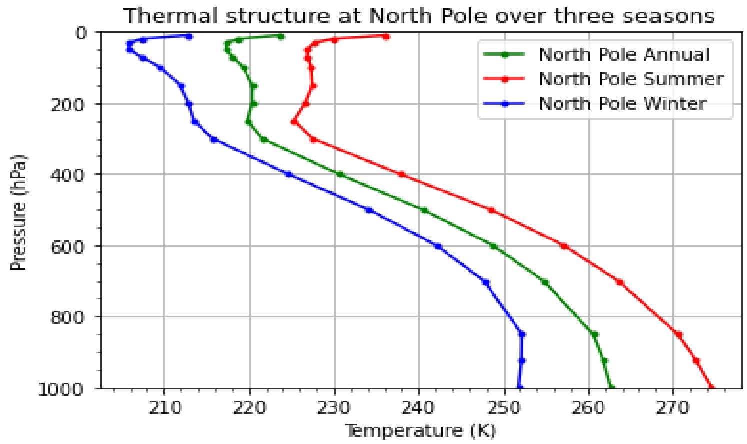
```
plt.plot(trosum,level,'g.-',label='Tropics')
plt.ylim(1000,0)
plt.title('Summer thermal structure of all regions')
plt.xlabel("temperature (K)")
plt.ylabel('pressure (hPa)')
plt.minorticks_on()
plt.legend()
plt.grid(True)
plt.show()

plt.plot(globaldjf,level,'y.-',label='Global')
plt.plot(indwin,level,'m.-',label='India')
plt.plot(polwin,level,'c.-',label='North Pole')
plt.plot(trowin,level,'g.-',label='Tropics')
plt.ylim(1000,0)
plt.title('Winter thermal structure of all regions')
plt.xlabel("temperature (K)")
plt.ylabel('pressure (hPa)')
plt.minorticks_on()
plt.legend()
plt.grid(True)
plt.show()

plt.plot(globalannual,level,'y.-',label='Global')
plt.plot(indiannual,level,'m.-',label='India')
plt.plot(polannual,level,'c.-',label='North Pole')
plt.plot(troannual,level,'g.-',label='Tropics')
plt.ylim(1000,0)
plt.title('Annual thermal structure of all regions')
plt.xlabel("temperature (K)")
plt.ylabel('pressure (hPa)')
plt.minorticks_on()
plt.legend()
plt.grid(True)
plt.show()
```



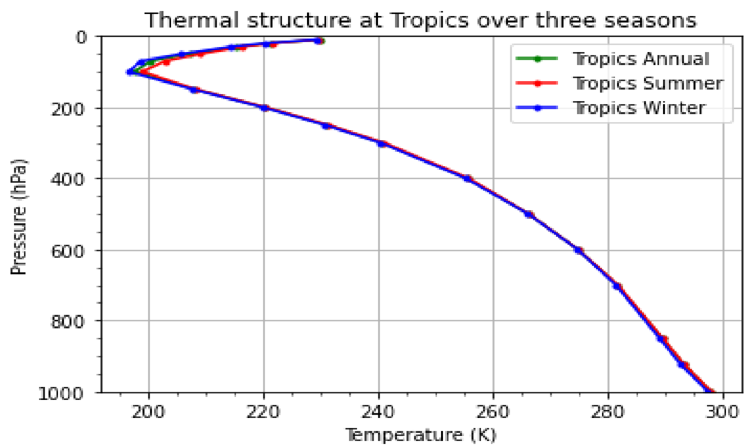
The vertical thermal structure across seasons is very similar for the globe.This can be attributed to the fact that northern and southern hemispheres experience opposite seasons at the same time of the year, thus maintaining the average.



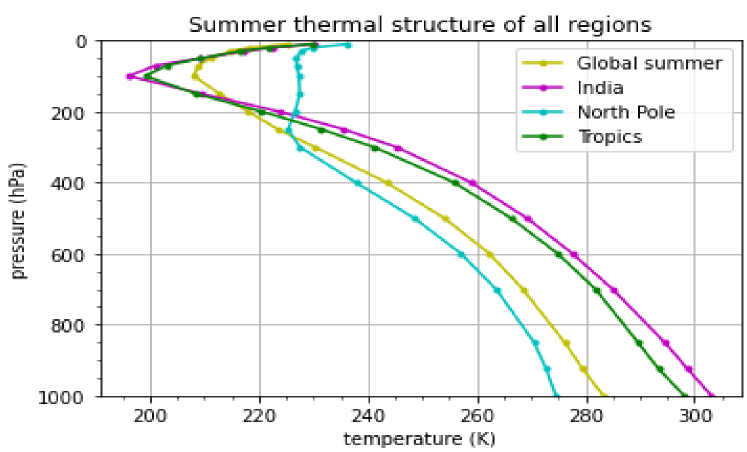
India is a tropical country. The difference mean temperature over summer and winter seasons is not very significant. And even that difference vanishes in the layers above tropopause because tropics receive almost same amount of sunlight throughout the year.



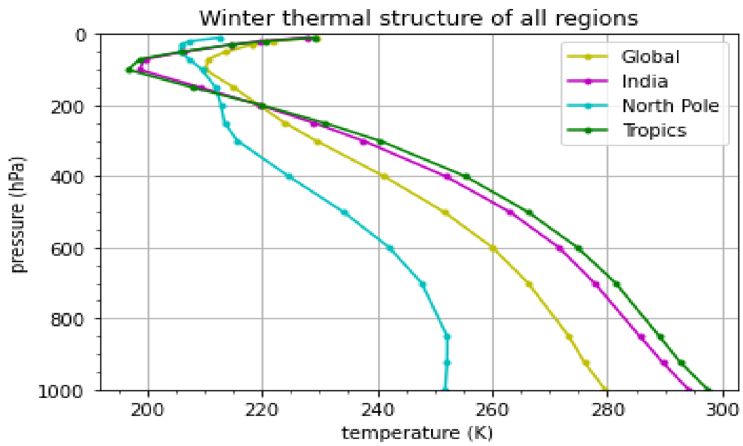
At the pole, the mean temperature across seasons has significant difference. This is because this region receives much scanty amount of sunlight during winters as compared to the summers due to earth's tilt on its axis.



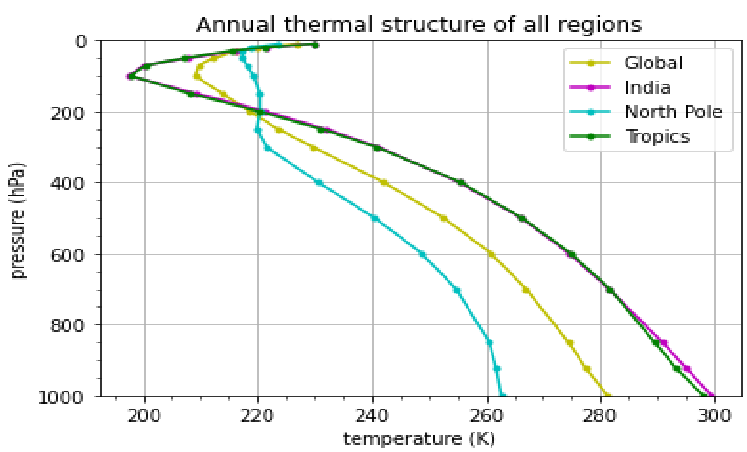
Since the Tropics receive plenty amount of sunlight throughout the year, we can see from the figure that the vertical thermal structure is almost the same across seasons.



From the figure, we see that the since India lies in the tropical region, it shares the same vertical thermal structure as the tropics.The hieght of the tropopause is less at the poles as compared to the tropics. The global trend is the average of the two, but more similar to that of the tropical region.



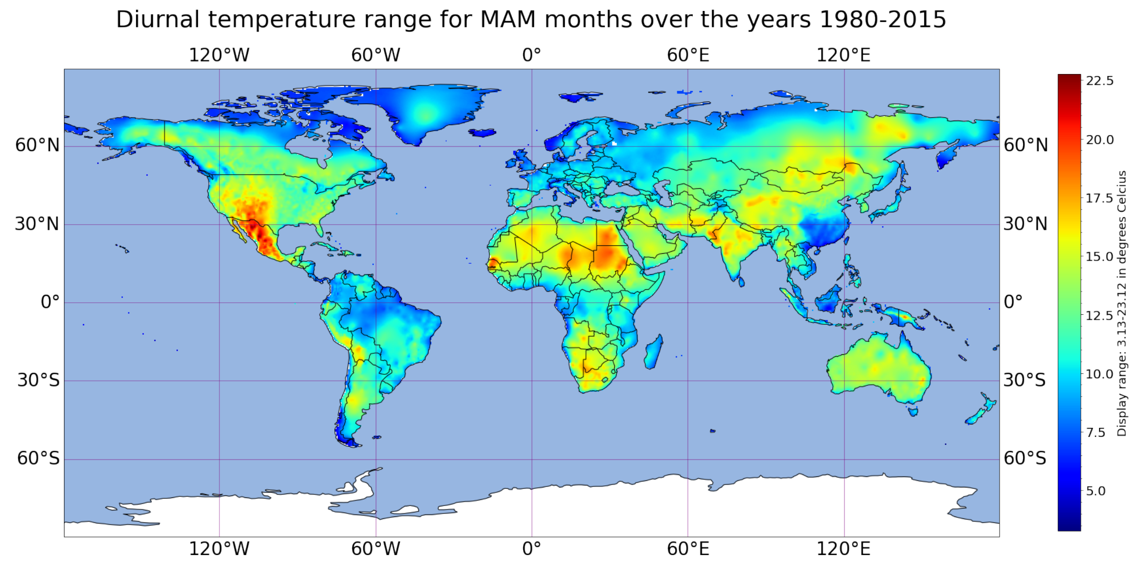
In the winter season, the vertical thermal structure is similar to the summers except for, in the polar region, the mean temperature experienced is higher.



The global trend is the average of summer and winter seasons, as per the expectation.

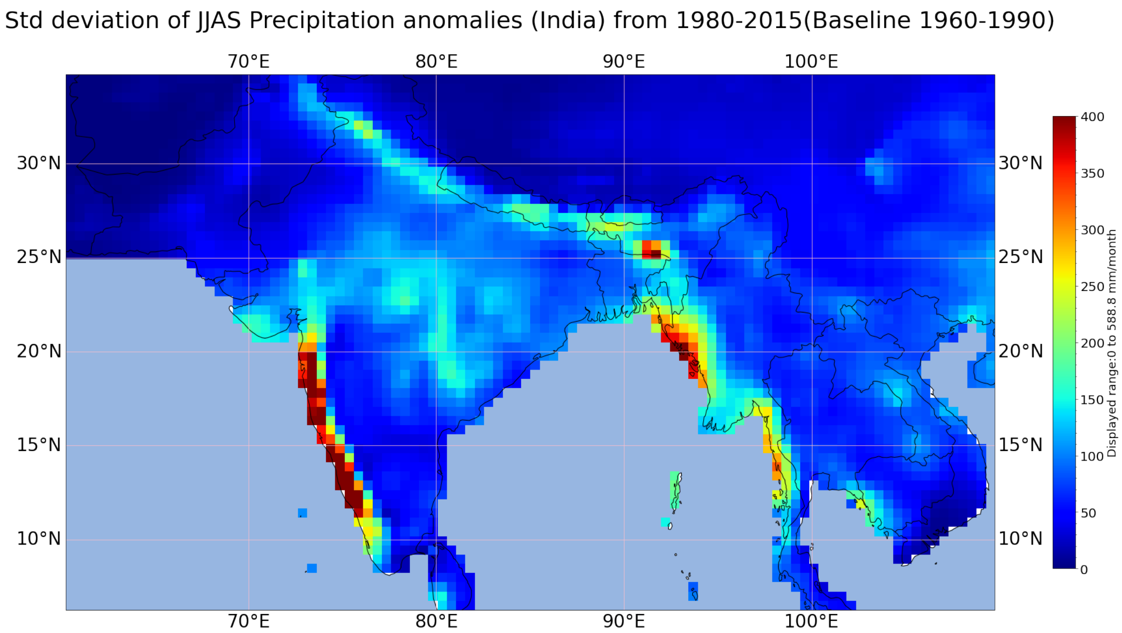
Data: Minimum and Maximum Temperature at the surface level.

```
# que2
import numpy as np
import matplotlib.pyplot as plt
import xarray as xr
import cartopy as cp
import cartopy.feature as cfeature
import cartopy.crs as crs

dtr=xr.open_dataset('dtrnew.nc')
dtr=dtr.tmx
dtr=dtr.mean(dim=['time','sfc'])

# Initialize the figure
fig = plt.figure(figsize=(32,32))

# use the Platecaree projection
ax = fig.add_subplot(1,1,1, projection=crs.PlateCarree(central_longitude=0.
 ↪0, globe=None))
graph=ax.imshow(dtr, extent=(dtr.lon.min(),dtr.lon.max(), dtr.lat.min(), dtr.
 ↪lat.max()),origin='lower',cmap='jet')
plt.title('Diurnal temperature range for MAM months over the years␣
 ↪1980-2015', fontsize='36',y=1.08)

# Add features to the map
ax.add_feature(cfeature.BORDERS,edgecolor='black')
ax.add_feature(cfeature.OCEAN)
ax.add_feature(cfeature.COASTLINE)

#setting the colorbar
cbar = fig.colorbar(graph, shrink=0.4)
cbar.minorticks_on()
cbar.ax.tick_params(axis='y', labelsize=20)
cbar.set_label('Display range: 3.13-23.12 in degrees Celcius',fontsize=18)

#setting the gridlines and axis labels using cartopy
gl=ax.gridlines(draw_labels=True, alpha=0.6 , color='purple')
gl.xlabel_style={'size':28}
gl.ylabel_style={'size':28}
```



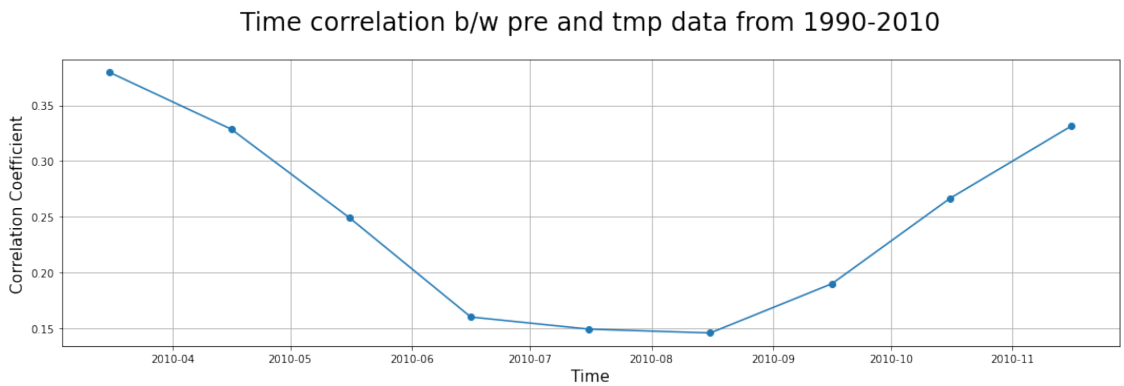
[40]:
```
# que3
import numpy as np
import matplotlib.pyplot as plt
import xarray as xr
import cartopy as cp
import cartopy.feature as cfeature
import cartopy.crs as crs

data = xr.open_dataset('std.anomaly.nc') #(("/home/student/EES405_Rimjhim/std.
↪anomaly.nc")
data = data.pre
data = data.squeeze(dim=['time'])

# Initialize the figure
fig = plt.figure(figsize=(32,32))

# use the Platecaree projection
ax = fig.add_subplot(1,1,1, projection=crs.PlateCarree(central_longitude=0,␣
↪globe=None))
graph=ax.imshow(data, extent=(data.lon.min(),data.lon.max(), data.lat.min(),␣
↪data.lat.max()),origin='lower',cmap='jet'
                ,vmin=0, vmax=400,)
plt.title('Std deviation of JJAS Precipitation anomalies (India) from␣
↪1980-2015(Baseline 1960-1990)'
          ,fontsize='36',y=1.08)

# Add feature to the map
ax.add_feature(cfeature.BORDERS,edgecolor='black')
```

```
ax.add_feature(cfeature.OCEAN)
ax.add_feature(cfeature.COASTLINE)

#adding the colorbar
cbar = fig.colorbar(graph, shrink=0.4,label='Displayed range:0 to 588.8 mm/
 ↪month')
cbar.minorticks_on()
cbar.ax.tick_params(axis='y', labelsize=20)
cbar.set_label('Displayed range:0 to 588.8 mm/month', fontsize=18)

#adding the grid lines
gl = ax.gridlines(draw_labels=True, alpha=1.0, color='pink')
gl.xlabel_style={'size':28}
gl.ylabel_style={'size':28}
```



[41]:
```
# que4
import numpy as np
import matplotlib.pyplot as plt
import xarray as xr
import cartopy as cp
import cartopy.feature as cfeature
import cartopy.crs as crs

# import data and remove redundant dimensions
data = xr.open_dataset('timecor.nc') #("/home/student/EES405_Rimjhim/timecor.nc)
data=data.pre
```

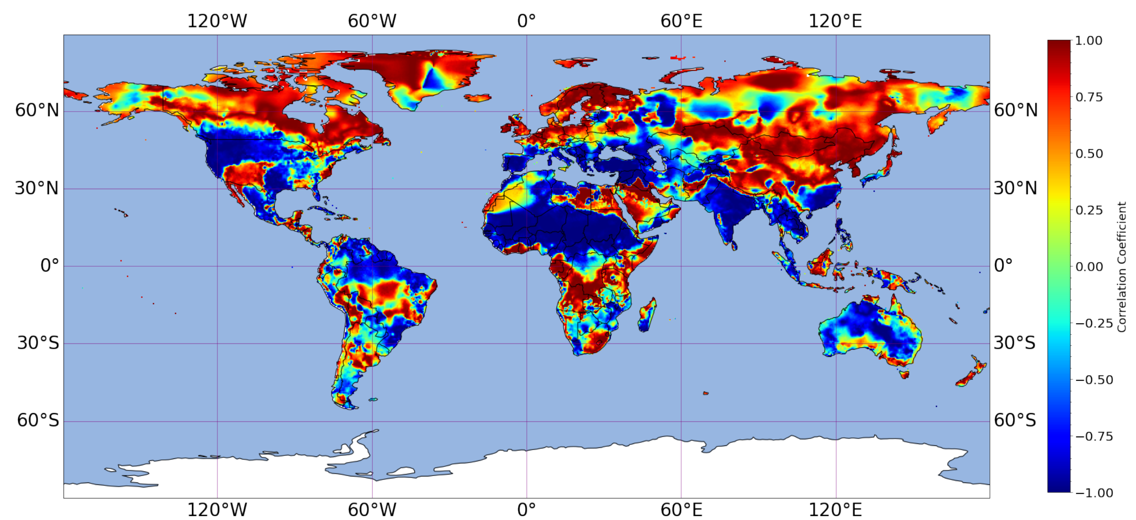
```
data=data.squeeze(dim=['lat','lon'])
time=data.time

# plotting
plt.plot(time,data,marker='o')
plt.title('Time correlation b/w pre and tmp data from 1990-2010',fontsize=24,y=1.
↪08)
plt.ylabel("Correlation Coefficient", fontsize=15)
plt.xlabel("Time",fontsize=15)
plt.grid()
# plt.rcParams['figure.figsize'] =
```



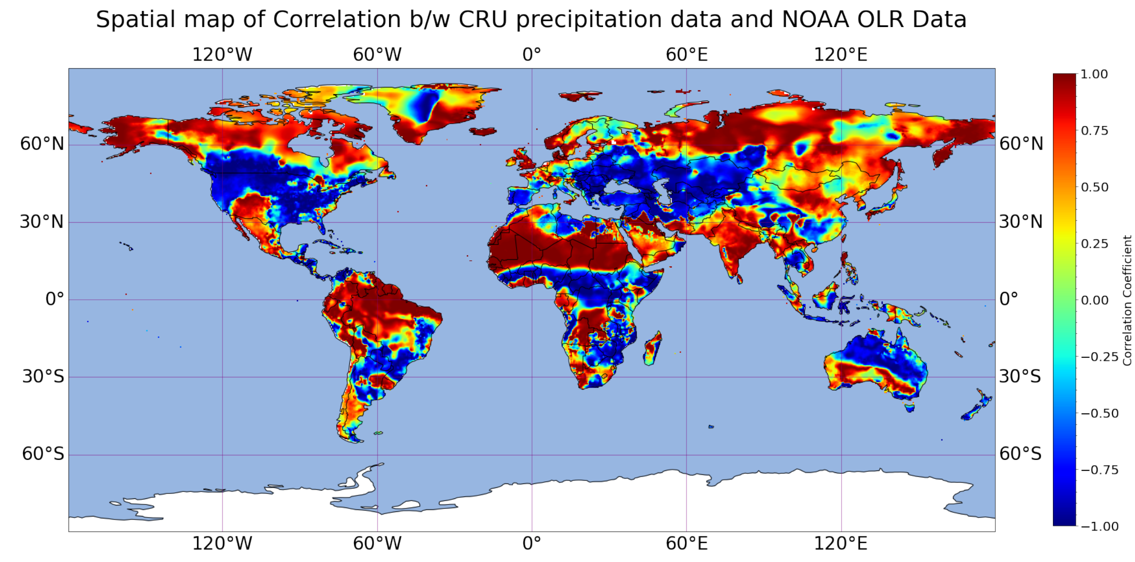
[42]:
```
# for que5
import numpy as np
import matplotlib.pyplot as plt
import xarray as xr
import cartopy as cp
import cartopy.feature as cfeature
import cartopy.crs as crs

# import data and remove extra variables
data = xr.open_dataset('spatialcorrelation.nc')#("/home/student/EES405_Rimjhim/
↪spatialcorrelation.nc)
data=data.pre
data = data.squeeze(dim=['time'])

# Plot using cartopy
# Initialize the figure
fig = plt.figure(figsize=(32,32))

# use the Platecaree projection
ax = fig.add_subplot(1,1,1, projection=crs.PlateCarree(central_longitude=0.0,␣
↪globe=None))
```

```
graph=ax.imshow(data, extent=(data.lon.min(),data.lon.max(), data.lat.min(),␣
↪data.lat.max()),origin='lower',cmap='jet')
plt.title('Spatial map of Correlation b/w Precipitation and Mean Temperature␣
↪from CRU data.', fontsize='36',y=1.08)

# Add features to the map
ax.add_feature(cfeature.BORDERS,edgecolor='black')
ax.add_feature(cfeature.OCEAN)
ax.add_feature(cfeature.COASTLINE)

#setting the colorbar
cbar = fig.colorbar(graph, shrink=0.4)
cbar.minorticks_on()
cbar.ax.tick_params(axis='y', labelsize=20)
cbar.set_label('Correlation Coefficient',fontsize=18)

#setting the gridlines and axis labels using cartopy
gl=ax.gridlines(draw_labels=True, alpha=0.6 , color='purple')
gl.xlabel_style={'size':28}
gl.ylabel_style={'size':28}
```

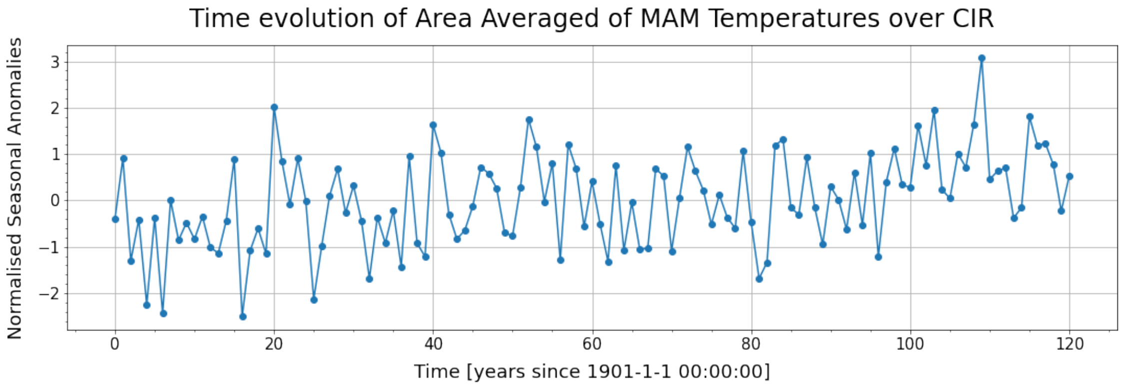
Spatial map of Correlation b/w Precipitation and Mean Temperature from CRU data.



[43]:
```python
# Que6
import numpy as np
import matplotlib.pyplot as plt
import xarray as xr
import cartopy as cp
import cartopy.feature as cfeature
import cartopy.crs as crs

# obtaining data and removing the extra variables

data = xr.open_dataset('spacor.pre.olr.nc') #("/home/student/EES405_Rimjhim/
 ↪spacor.pre.olr.nc")
data=data.pre
data=data.squeeze(['time'])

# Plot using cartopy
# Initialize the figure
fig = plt.figure(figsize=(32,32))

# use the Platecaree projection
ax = fig.add_subplot(1,1,1, projection=crs.PlateCarree(central_longitude=0.0,␣
 ↪globe=None))
graph=ax.imshow(data, extent=(data.lon.min(),data.lon.max(), data.lat.min(),␣
 ↪data.lat.max()),origin='lower',cmap='jet')
plt.title('Spatial map of Correlation b/w CRU precipitation data and NOAA OLR␣
 ↪Data', fontsize='36',y=1.08)

# Add features to the map
ax.add_feature(cfeature.BORDERS,edgecolor='black')
ax.add_feature(cfeature.OCEAN)
ax.add_feature(cfeature.COASTLINE)

#setting the colorbar
cbar = fig.colorbar(graph, shrink=0.4)
cbar.minorticks_on()
cbar.ax.tick_params(axis='y', labelsize=20)
cbar.set_label('Correlation Coefficient',fontsize=18)

#setting the gridlines and axis labels
gl=ax.gridlines(draw_labels=True, alpha=0.6 , color='purple')
gl.xlabel_style={'size':28}
gl.ylabel_style={'size':28}
```



[44]:
```
# for que7
import numpy as np
import matplotlib.pyplot as plt
import xarray as xr
import cartopy as cp
import cartopy.feature as cfeature
import cartopy.crs as crs

# importing data and removing extra variables and dimensions
data = xr.open_dataset('norm.ano.nc',decode_times=False) #"/home/student/
 ↪EES405_Rimjhim/norm.ano.nc"
data=data.tmp
data=data.squeeze(dim=['lat','lon'])

# plotting the data
plt.plot(data,marker='o')
plt.title('Time evolution of Area Averaged of MAM Temperatures over␣
 ↪CIR',fontsize=24,y=1.04)
plt.ylabel("Normalised Seasonal Anomalies", fontsize=18,labelpad=10)
plt.xlabel('Time [years since 1901-1-1 00:00:00]',fontsize=18,labelpad=10)

plt.grid()
plt.yticks(fontsize=15)
plt.xticks(fontsize=15)
plt.minorticks_on()
plt.rcParams['figure.figsize'] = [20,10]
```


Time evolution of Area Averaged of MAM Temperatures over CIR
Normalised Seasonal Anomalies
3
2
1
0
−1
−2
0
20
40
60
80
100
120
Time [years since 1901-1-1 00:00:00]