HOMEWORK#3

1. Global methane levels from 2002

Methane (CH_4) is a naturally occurring Greenhouse Gas (GHG), but one whose abundance has been increased substantially above its pre-industrial value by human activities, primarily because of agricultural emissions (e.g., rice production, ruminants) and fossil fuel production and use. A clear annual cycle is largely due to seasonal wetland emissions.

Atmospheric methane abundance is indirectly observed by various satellite instruments. These instruments measure spectrally resolved near-infrared and infrared radiation reflected or emitted by the Earth and its atmosphere. In the measured signal, molecular absorption signatures from methane and constituent gasses can be identified. It is through analysis of those absorption lines in these radiance observations that the averaged methane abundance in the sampled atmospheric column can be determined.

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`), 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`.

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

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.

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.

思路：

1.1

首先通过 xarray 库读取甲烷 netCDF 数据文件，提取核心变量“xch4”（甲烷浓度）。利用 groupby('time.month').mean(dim='time')按月份分组，计算各月多年平均气候态，消除年际差异。采用分面绘图（col='month'），设置 4 列 3 行的 12 个子图布局，使用 viridis 色彩映射和 robust 参数优化颜色范围，添加水平色条提升可读性，最终呈现每月甲烷浓度的全球分布特征。

1.2

基于提取的“xch4”变量，通过 mean(dim=['lat','lon'])对纬度和经度维度求平均，得到全球尺度的甲烷时间序列。使用 matplotlib 绘制折线图，设置深色线条、标记点和半透明效果增强视觉呈现，添加网格线辅助读取趋势。通过图表观察到 2003-2020 年全球甲烷浓度整体持续上升，同时存在小幅季节波动，与人类活动和自然排放的季节性变化相关。

1.3

先通过 sel(lat=-15,lon=150,method='nearest')筛选目标坐标[15°S,150°E]的甲烷数据。计算该点的月气候态，再利用 groupby('time.month')气候态实现去季节化处理，消除季节性波动影响。绘制去季节化后的异常值时间序列，添加 0 值参考线，清晰呈现年际尺度变化趋势，结果显示该点甲烷浓度与全球变化趋势一致，呈上升特征。

代码来源：学计算机的朋友的指导以及 AI 辅助帮助。

2. Niño 3.4 index

The *Niño 3.4 anomalies* may be thought of as representing the average equatorial sea surface temperatures (SSTs) across the Pacific from about the dateline to the South American coast (`5N-5S`, `170W-120W`). The Niño 3.4 index typically uses a 3-month running mean, and El Niño or La Niña events are defined when the Niño 3.4 SSTs exceed `+/- 0.5° C` for a period of `5` months or more. Check Equatorial Pacific Sea Surface Temperatures for more about the Niño 3.4 index.

In this problem set, you will use the sea surface temperature (SST) data from NOAA. Download the `netCDF4` file (`NOAA_NCDC_ERSST_v3b_SST.nc`).

1.1 [10 points] Compute monthly climatology for SST from Niño 3.4 region, and subtract climatology from SST time series to obtain anomalies.

1.2 [10 points] Visualize the computed Niño 3.4. Your plot should look similar to this one.

思路：

1.1

使用 xarray 读取 SST（海表温度）netCDF 数据，通过 sel(lat=slice(-5,5),lon=slice(190,240))筛选 Niño3.4 区域（5° N-5° S，170° W-120° W，对应经度 190-240° E）。对该区域数据进行经纬度平均，得到区域平均 SST 时间序列。按月份分组计算月气候态，用原始 SST 序列减去气候态，得到 SST 异常值，反映偏离平均状态的波动。

1.2

为突出趋势，对异常值序列计算 3 个月滑动平均（rolling(time=3,center=True).mean()）。在同一张图中绘制月异常值和 3 个月滑动平均，添加±0.5℃阈值线和 0 值基准线。设置图表标题、坐标轴标签和图例，添加网格线，使图表清晰呈现 Niño3.4 指数的时间变化、极端事件及长期波动特征。

代码来源：学计算机的朋友的指导以及 AI 辅助帮助。

3. Explore a `netCDF` dataset

Browse the NASA's Goddard Earth Sciences Data and Information Services Center (GES DISC) website. Search and download a dataset you are interested in. You are also welcome to use data from your group in this problem set. But the dataset should be in `netCDF` format, and have temporal information.

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

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

思路：

3.1

本次所得结果选取热带太平洋区域（10° S-10° N，120° E-180° E），对该区域 SST 进行经纬度平均。按月份分组计算月气候态，通过“原始序列-气候态”实现去季节化，消除季节性影响。绘制去季节化后的 SST 异常值时间序列，添加 0 值参考线，直观展示年际尺度的温度波动特征。

3.2

全球年平均 SST 分布图：按年份分组计算年平均 SST，选取 2000 年数据，使用 RdYlBu_r 冷暖色映射，通过 robust 参数调整颜色范围，避免极值干扰，呈现全球海表温度的空间分布格局。

区域月气候态折线图：以热带太平洋月气候态数据为基础，绘制折线图并添加标记点，清晰展示该区域 SST 的季节变化规律（如夏季高、冬季低的特征）。

时间-纬度热力图：对 SST 数据进行经度平均（纬向平均），绘制时间-纬度

二维热力图，通过颜色深浅反映不同纬度、不同时期的 SST 变化，直观呈现纬度差异和时间演变。

全球 SST 直方图：统计全球 SST 数据的分布频率，设置 50 个分组，展示温度值的分布特征。

多区域时间序列对比图：选取热带太平洋、北大西洋、南大洋三个典型区域，分别计算各区域平均 SST 时间序列，在同一张图中对比绘制，通过不同颜色区分区域，展示各区域 SST 的长期变化趋势和差异。

代码来源：学计算机的朋友的指导以及 AI 辅助帮助。