Question2

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0.0.2 Question 2A

I extracted solar_data.tar.gz, which contains 10 .txt files from 2014 to 2023. Each file starts with metadata, followed by daily solar data in table format. I checked all 10 files and confirmed they have the same structure: date, radio flux, sunspot data, solar field, X-ray flares (C/M/X), and optical flares (S, 1, 2, 3). Fields are whitespace-separated and consistent across files.

In [23]:
```
import os
import tarfile

!cp /public/bmort/python/solar_data.tar.gz .
with tarfile.open("solar_data.tar.gz", "r:gz") as tar:
    tar.extractall("solar_data")

data_path = "solar_data/solar_data"
txt_files = sorted([f for f in os.listdir(data_path) if f.endswith('.txt')])

for fname in txt_files:
    print(f"\n Examining file: {fname}")
    file_path = os.path.join(data_path, fname)
    with open(file_path, 'r') as f:
        line_count = 0
        for line in f:
            if not line.startswith('#') and not line.startswith(':') and line.strip()
                print(line.strip())
                line_count += 1
            if line_count >= 4:  # Only show 4 data lines per file
                break
```

```
 Examining file: 2014_DSD.txt
2014 01 01   160    106      610      1    -999   C1.1    3   1   0   7   0   1   0
2014 01 02   161    133     1410      1    -999   C1.5    6   2   0   5   1   0   0
2014 01 03   182    162     1570      0    -999   C1.2    9   2   0  14   0   0   0
2014 01 04   215    178     1710      1    -999   C1.7    4   3   0  10   0   1   0

 Examining file: 2015_DSD.txt
```

```
2015 01 01  138    101      870       1    -999   B4.9   3  0  0  9  0  0  0
2015 01 02  146    113     1250       1    -999   B4.9   3  0  0  9  0  0  0
2015 01 03  149    122     1300       0    -999   B5.7  10  1  0 13  1  0  0
2015 01 04  150    124     1220       0    -999   B6.7   5  1  0 13  0  1  0

 Examining file: 2016_DSD.txt
2016 01 01   98     40      140       2    -999   B3.4   3  1  0  2  0  0  0
2016 01 02  100     52      140       1    -999   B5.8   0  0  0  1  0  0  0
2016 01 03  102     50      170       0    -999   B3.1   0  0  0  1  0  0  0
2016 01 04   95     60      160       0    -999   B2.2   0  0  0  0  0  0  0

 Examining file: 2017_DSD.txt
2017 01 01   73      0        0       1    -999   A5.7   0  0  0  0  0  0  0
2017 01 02   73      0        0       0    -999   A5.7   0  0  0  0  0  0  0
2017 01 03   73     11        0       1    -999   A5.5   0  0  0  0  0  0  0
2017 01 04   72      0        0       0    -999   A5.4   0  0  0  0  0  0  0

 Examining file: 2018_DSD.txt
2018 01 01   69      0        0       0    -999   A3.5   0  0  0  0  0  0  0
2018 01 02   70      0        0       0    -999   A3.2   0  0  0  0  0  0  0
2018 01 03   71      0        0       0    -999   A3.1   0  0  0  0  0  0  0
2018 01 04   70     13       20       1    -999   A3.1   0  0  0  0  0  0  0

 Examining file: 2019_DSD.txt
2019 01 01   72     13       10       1    -999   A1.0   0  0  0  0  0  0  0
2019 01 02   75     16       30       0    -999   A1.9   0  0  0  1  0  0  0
2019 01 03   73     16       90       0    -999   A2.3   0  0  0  0  0  0  0
2019 01 04   72     13       50       0    -999   A1.5   0  0  0  0  0  0  0

 Examining file: 2020_DSD.txt
2020 01 01   72      0        0       0    -999   A8.0   0  0  0  0  0  0  0
2020 01 02   72     13       20       1    -999   A8.3   0  0  0  0  0  0  0
2020 01 03   71     13       20       0    -999   A8.6   0  0  0  0  0  0  0
2020 01 04   72     11       10       0    -999   A8.5   0  0  0  0  0  0  0

 Examining file: 2021_DSD.txt
2021 01 01   80     23      190       0    -999      *   0  0  0  0  0  0  0
2021 01 02   82     22      120       0    -999      *   0  0  0  0  0  0  0
2021 01 03   80      0        0       0    -999      *   0  0  0  0  0  0  0
2021 01 04   78      0        0       0    -999      *   0  0  0  0  0  0  0

 Examining file: 2022_DSD.txt
2022 01 01   94     52      440       1    -999      *   1  1  0  1  0  0  0
2022 01 02   89     25      340       0    -999      *   1  0  0  0  0  0  0
2022 01 03   84     12      140       0    -999      *   0  0  0  0  0  0  0
2022 01 04   86     12       30       1    -999      *   0  0  0  0  0  0  0

 Examining file: 2023_DSD.txt
```

```
2023 01 01   153      94      1220        1      -999       *    9   0   0  12   0   0   0
2023 01 02   146      94      1100        0      -999       *    9   0   0   7   1   0   0
2023 01 03   149      89       930        0      -999       *    5   0   0   1   0   0   0
2023 01 04   151      86       550        0      -999       *    3   0   0   4   0   1   0
```

0.0.3 Question 2B

```
In [24]: import pandas as pd
         import glob

         data_files = sorted(glob.glob('./solar_data/solar_data/*.txt'))

         col_names = [
             'Date', 'RadioFlux', 'SunspotNumber', 'SunspotArea', 'NewRegions',
             'SolarMeanField', 'XrayBkgd', 'Xray_C', 'Xray_M', 'Xray_X',
             'Optical_S', 'Optical_1', 'Optical_2', 'Optical_3'
         ]

         df_list = []

         for f in data_files:
             try:
                 df = pd.read_csv(
                     f,
                     delim_whitespace=True,
                     skiprows=13,
                     comment='#',
                     header=None
                 )

                 year = df[0].astype(str)
                 month = df[1].astype(str).str.zfill(2)
                 day = df[2].astype(str).str.zfill(2)
                 date_str = year + '-' + month + '-' + day

                 df['Date'] = date_str

                 df.columns = ['Year', 'Month', 'Day', 'RadioFlux', 'SunspotNumber', 'SunspotA
                               'SolarMeanField', 'XrayBkgd', 'Xray_C', 'Xray_M', 'Xray_X',
                               'Optical_S', 'Optical_1', 'Optical_2', 'Optical_3', 'Date']

                 df = df.drop(columns=['Year', 'Month', 'Day'])

                 df_list.append(df)

             except Exception as e:
                 print(f"Failed to load {f}: {e}")
```

```
df_all = pd.concat(df_list, ignore_index=True)
df_all.head()
```

Out[24]:

```
   RadioFlux  SunspotNumber  SunspotArea  NewRegions  SolarMeanField XrayBkgd  \
0        160            106          610           1            -999     C1.1
1        161            133         1410           1            -999     C1.5
2        182            162         1570           0            -999     C1.2
3        215            178         1710           1            -999     C1.7
4        218            225         1790           0            -999     C1.8

   Xray_C  Xray_M  Xray_X  Optical_S  Optical_1  Optical_2  Optical_3  \
0       3       1       0          7          0          1          0
1       6       2       0          5          1          0          0
2       9       2       0         14          0          0          0
3       4       3       0         10          0          1          0
4       3       0       0         14          0          0          0

         Date
0  2014-01-01
1  2014-01-02
2  2014-01-03
3  2014-01-04
4  2014-01-05
```

In [25]:

```
import numpy as np

numeric_cols = df_all.columns.drop(['Date', 'XrayBkgd']).tolist()

df_all[numeric_cols] = df_all[numeric_cols].astype(float)

df_all[numeric_cols] = df_all[numeric_cols].replace(-999, np.nan)

summary = df_all[numeric_cols].describe()
display(summary)
```

```
         RadioFlux  SunspotNumber  SunspotArea   NewRegions  SolarMeanField  \
count  3650.000000    3650.000000  3650.000000  3650.000000             0.0
mean    100.773699      49.189863   344.112877     0.433973             NaN
std      35.477323      51.333475   449.820622     0.735244             NaN
min      -1.000000       0.000000     0.000000     0.000000             NaN
25%      71.000000       0.000000     0.000000     0.000000             NaN
50%      85.000000      31.000000   160.000000     0.000000             NaN
75%     126.000000      81.000000   540.000000     1.000000             NaN
max     343.000000     296.000000  3120.000000     6.000000             NaN

            Xray_C       Xray_M       Xray_X    Optical_S    Optical_1  \
count  3650.000000  3650.000000  3650.000000  3650.000000  3650.000000
```

```
mean       2.498904     0.261096     0.011781     3.291507     0.210959
std        3.902361     0.854465     0.112878     5.588125     0.629407
min        0.000000     0.000000     0.000000     0.000000     0.000000
25%        0.000000     0.000000     0.000000     0.000000     0.000000
50%        0.000000     0.000000     0.000000     0.000000     0.000000
75%        4.000000     0.000000     0.000000     4.000000     0.000000
max       30.000000    11.000000     2.000000    55.000000     7.000000

         Optical_2    Optical_3
count  3650.000000  3650.000000
mean      0.034247     0.003836
std       0.194976     0.061822
min       0.000000     0.000000
25%       0.000000     0.000000
50%       0.000000     0.000000
75%       0.000000     0.000000
max       2.000000     1.000000
```

0.0.4 Question 2B Summary

Loaded all yearly solar data into a single Pandas DataFrame.

Data cleaning actions: - Combined "Year, Month, Day" into a single Date column. - Replaced -999 with NaN to handle missing values. - Converted numeric columns to "float" type, excluding non-numeric ones like "XrayBkgd".

Summary statistics: - The numerical columns have different magnitudes and ranges. - For example, "SunspotArea" ranges up to 3120, while "Xray_M", "Optical_2", etc., have mostly zeros and small values. - This shows the variables are not on the same scale. - Some columns show potential outliers, especially those with large max values far above the 75th percentile.

0.0.5 Question2C

```
In [26]: max_flux = df_all['RadioFlux'].max()
         max_days = df_all[df_all['RadioFlux'] == max_flux][['Date', 'RadioFlux']]

         min_flux = df_all['RadioFlux'].min()
         min_days = df_all[df_all['RadioFlux'] == min_flux][['Date', 'RadioFlux']]

         display(max_days)
         display(min_days)
```

```
            Date  RadioFlux
3333  2023-02-17      343.0


            Date  RadioFlux
3271  2022-12-16       -1.0
```

2023-02-17 had the highest value for the radio flux2022-12-16 had the lowest value for the radio flux.

0.0.6 Question2D

```
In [27]: df_all['TotalFlares'] = df_all[['Optical_S', 'Optical_1', 'Optical_2', 'Optical_3']].s

         max_flare_value = df_all['TotalFlares'].max()
         max_flare_days = df_all[df_all['TotalFlares'] == max_flare_value][['Date', 'TotalFlare

         no_flare_days_count = (df_all['TotalFlares'] == 0).sum()

         print("Day(s) with highest solar flares:")
         display(max_flare_days)

         print(f" Number of days with no solar flares: {no_flare_days_count}")
```

```
Day(s) with highest solar flares:


            Date  TotalFlares
3327  2023-02-11         60.0


 Number of days with no solar flares: 1823
```

Day(s) with the highest number of solar flares: 2023-02-11 had the highest number of solar flares, with a total of 60 flares observed. Number of days with no solar flares: There were 1,823 days with zero solar flares recorded.

0.0.7 Question 2E

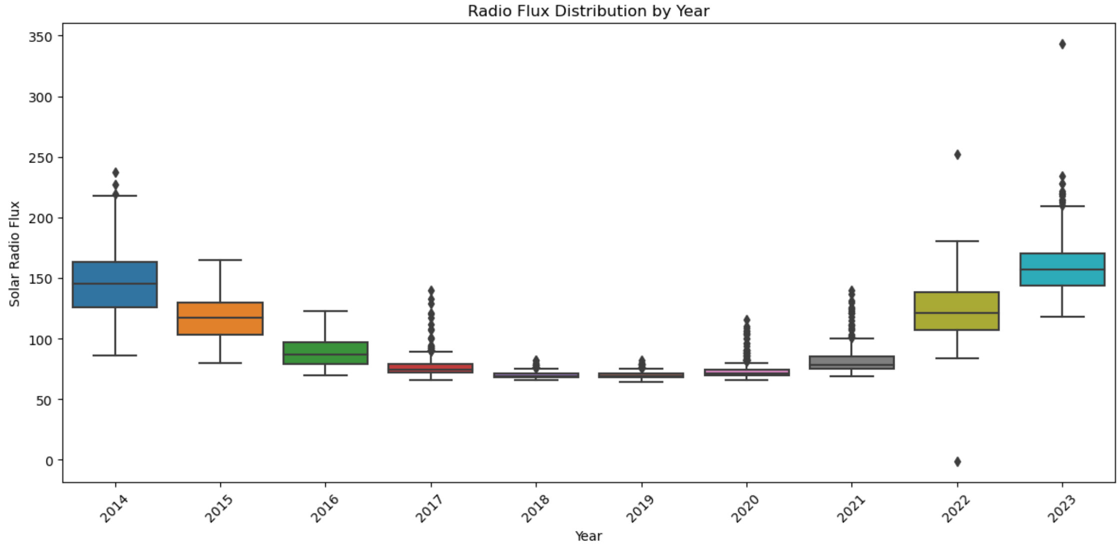
```
In [29]: import seaborn as sns
         import matplotlib.pyplot as plt

         df_all['Date'] = pd.to_datetime(df_all['Date'])

         df_all['Year'] = df_all['Date'].dt.year

         plt.figure(figsize=(12, 6))
         sns.boxplot(x='Year', y='RadioFlux', data=df_all)

         plt.title('Radio Flux Distribution by Year')
         plt.xlabel('Year')
         plt.ylabel('Solar Radio Flux')
         plt.xticks(rotation=45)
         plt.tight_layout()
         plt.show()
```



0.0.8 Question2F

In [30]:
```
from sklearn.model_selection import train_test_split

train_df, test_df = train_test_split(df_all, test_size=0.2, random_state=42)

print(f"Training set size: {len(train_df)}")
print(f"Testing set size: {len(test_df)}")
```

```
Training set size: 2920
Testing set size: 730
```

0.0.9 Question2G and H

In [36]:
```
from sklearn.linear_model import LinearRegression
from sklearn.metrics import mean_squared_error, r2_score

features = ['SunspotNumber', 'Xray_C', 'Xray_M', 'Xray_X',
            'Optical_S', 'Optical_1', 'Optical_2', 'Optical_3']
target = 'RadioFlux'

train_clean = train_df.dropna(subset=features + [target])
test_clean = test_df.dropna(subset=features + [target])

X_train = train_clean[features]
y_train = train_clean[target]
X_test = test_clean[features]
y_test = test_clean[target]
```

```
model = LinearRegression()
model.fit(X_train, y_train)

y_pred = model.predict(X_test)

mse = mean_squared_error(y_test, y_pred)
r2 = r2_score(y_test, y_pred)

print("Mean Squared Error:", round(mse, 2))
print("R-squared:", round(r2, 4))
```

```
Mean Squared Error: 173.82
R-squared: 0.8644
```

The model predicts the solar radio flux quite well, with an Rš score of approximately 0.86, indicating that about 86% of the variability in solar radio flux can be explained by sunspot number and solar flare activity. The accuracy is good because solar activity indicators like sunspots and flares have a strong correlation with radio flux. However, the prediction is not perfect due to possible noise in the data or other influencing factors not included in the model.

0.0.10 Question2I

```
In [37]: import pandas as pd

         input_data = pd.DataFrame([{
             'SunspotNumber': 96,
             'Xray_C': 1,
             'Xray_M': 0,
             'Xray_X': 0,
             'Optical_S': 0,
             'Optical_1': 0,
             'Optical_2': 0,
             'Optical_3': 0
         }])

         predicted_flux = model.predict(input_data)[0]
         print(f"Predicted Solar Radio Flux: {predicted_flux:.2f}")
```

```
Predicted Solar Radio Flux: 122.72
```

The predicted solar radio flux for a day with 96 sunspots and a single C-class X-ray flare is approximately 122.72.

We are reasonably confident in this prediction because the model achieves a high Rš score of approximately 0.86. However, the prediction is not perfect due to noise in the data and other influencing factors not captured in the model.