UKBMS_HADUK_Exploration1111

October 2, 2022

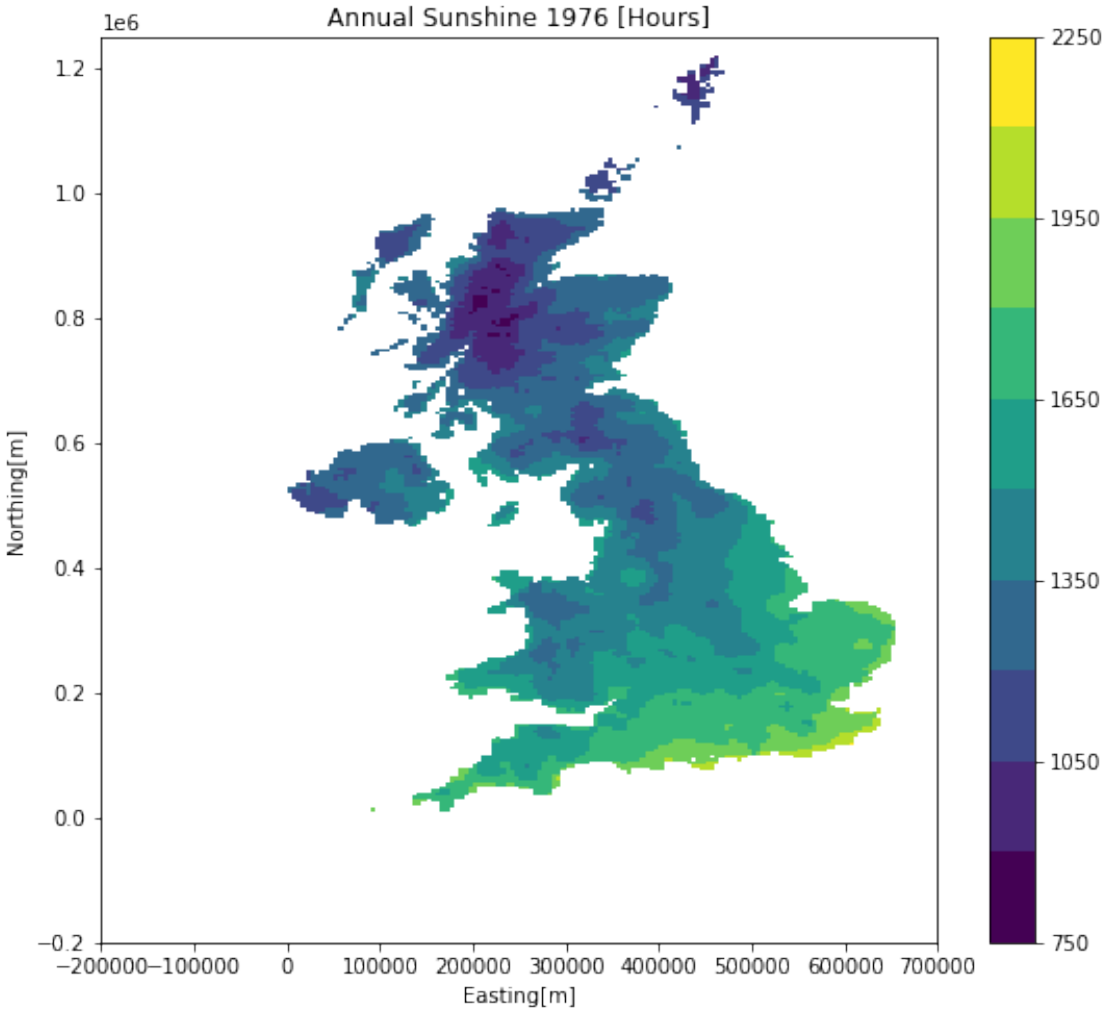
[ ]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import xarray as xr
import glob
from copy import deepcopy
import geopandas
import shapely
import matplotlib.colors as colors
```

[ ]:
```
#loading raw ukbms data
site_indices = pd.read_csv('ukbms2020csv/ukbmssiteindices2020.
 ↪csv',encoding='cp1252')
```

[ ]:
```
#loading combined site indices and climate data, combined using 'nearest'␣
 ↪method of selection see HADUK_Intermediate.py
indices_climate = pd.read_csv('site_climate.csv')

#dropping the first column -> previous index
indices_climate.drop(columns=indices_climate.columns[0], axis=1, inplace=True)
# indices_climate.head
```

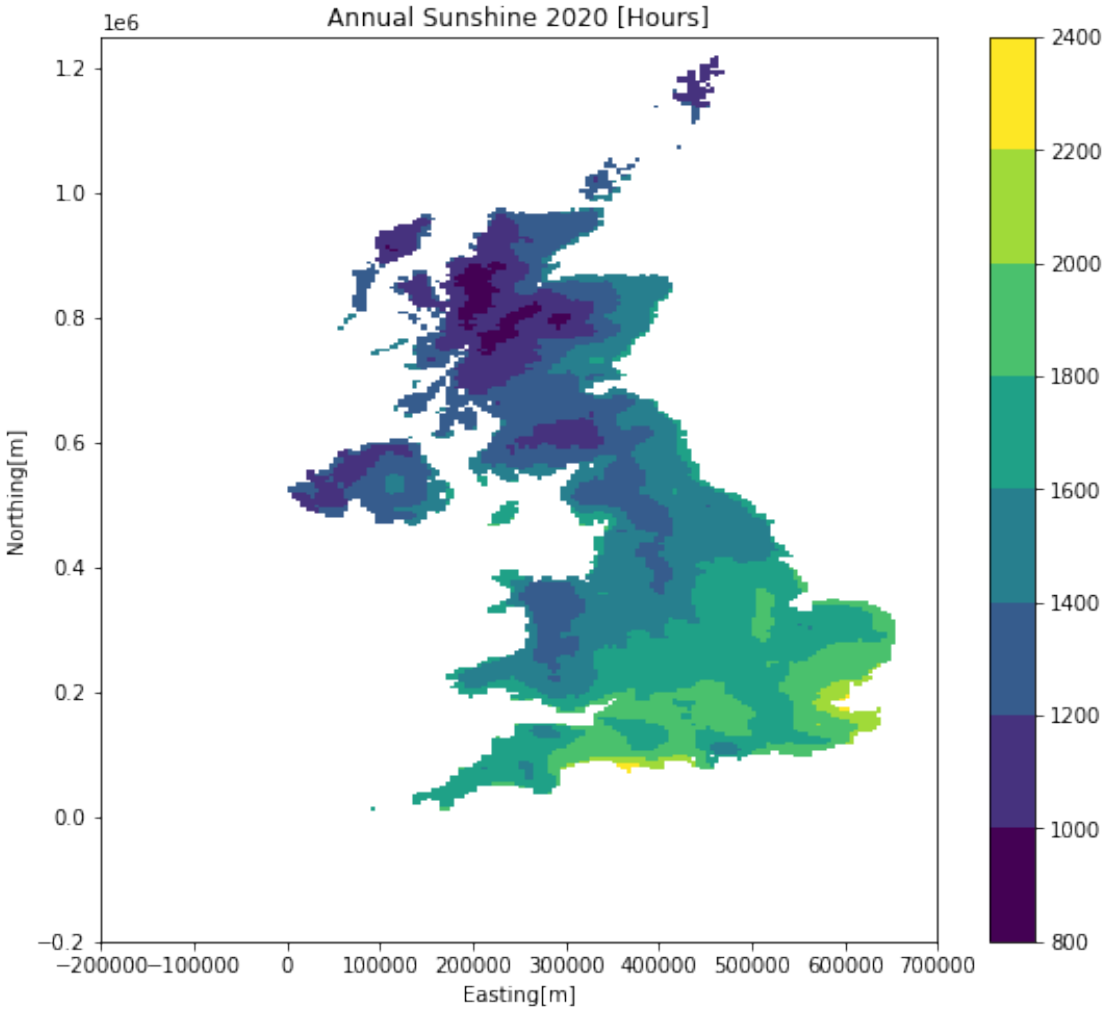
[ ]:
```
#raw climatic variables
airtemp_filenames = glob.glob('/Users/Louisa/Desktop/MScProject/HADUKAnnual␣
 ↪(1973-2020)/annual mean air temp/*.nc')
rainfall_filenames = glob.glob('/Users/Louisa/Desktop/MScProject/HADUKAnnual␣
 ↪(1973-2020)/annual rainfall/*.nc')
humidity_filenames = glob.glob('/Users/Louisa/Desktop/MScProject/HADUKAnnual␣
 ↪(1973-2020)/relative humidity/*.nc')
sunshine_filenames = glob.glob('/Users/Louisa/Desktop/MScProject/HADUKAnnual␣
 ↪(1973-2020)/sunshine hours/*.nc')
airtemp_dat = xr.open_mfdataset(airtemp_filenames)
rainfall_dat = xr.open_mfdataset(rainfall_filenames)
humidity_dat = xr.open_mfdataset(humidity_filenames)
sunshine_dat = xr.open_mfdataset(sunshine_filenames)
```

[ ]:
```
#sun 1976
plt.figure(figsize=[9,8])
sunplt1976 = sunshine_dat['sun'].sel(time='1976')
sunplt1976.plot(add_labels=False, levels= 10) #removing xarray labels
plt.title('Annual Sunshine 1976 [Hours]')
plt.xlabel('Easting[m]')
plt.ylabel('Northing[m]')
plt.savefig('figures/Sunshine 1976.png')
```



[ ]:
```
#sun 2020
plt.figure(figsize=[9,8])
sunplt2020 = sunshine_dat['sun'].sel(time='2020')
sunplt2020.plot(add_labels=False, levels = 10)
plt.title('Annual Sunshine 2020 [Hours]')
plt.xlabel('Easting[m]')
```

```
plt.ylabel('Northing[m]')
plt.savefig('figures/Sunshine 2020.png')
```

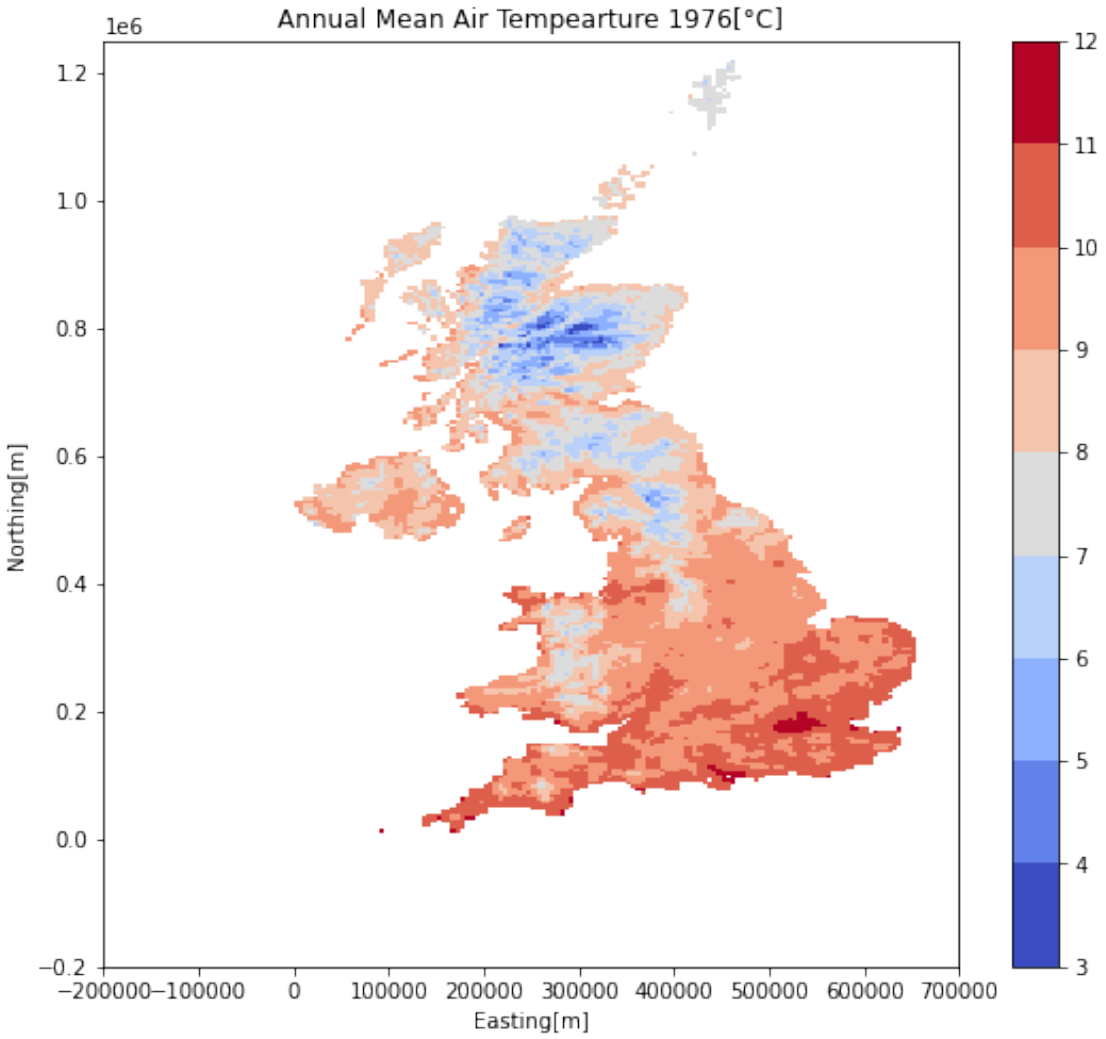


[ ]:
```
print(sunplt1976.to_masked_array().mean())
print(sunplt2020.to_masked_array().mean())
```

```
1427.7008828983269
1496.6031684085676
```

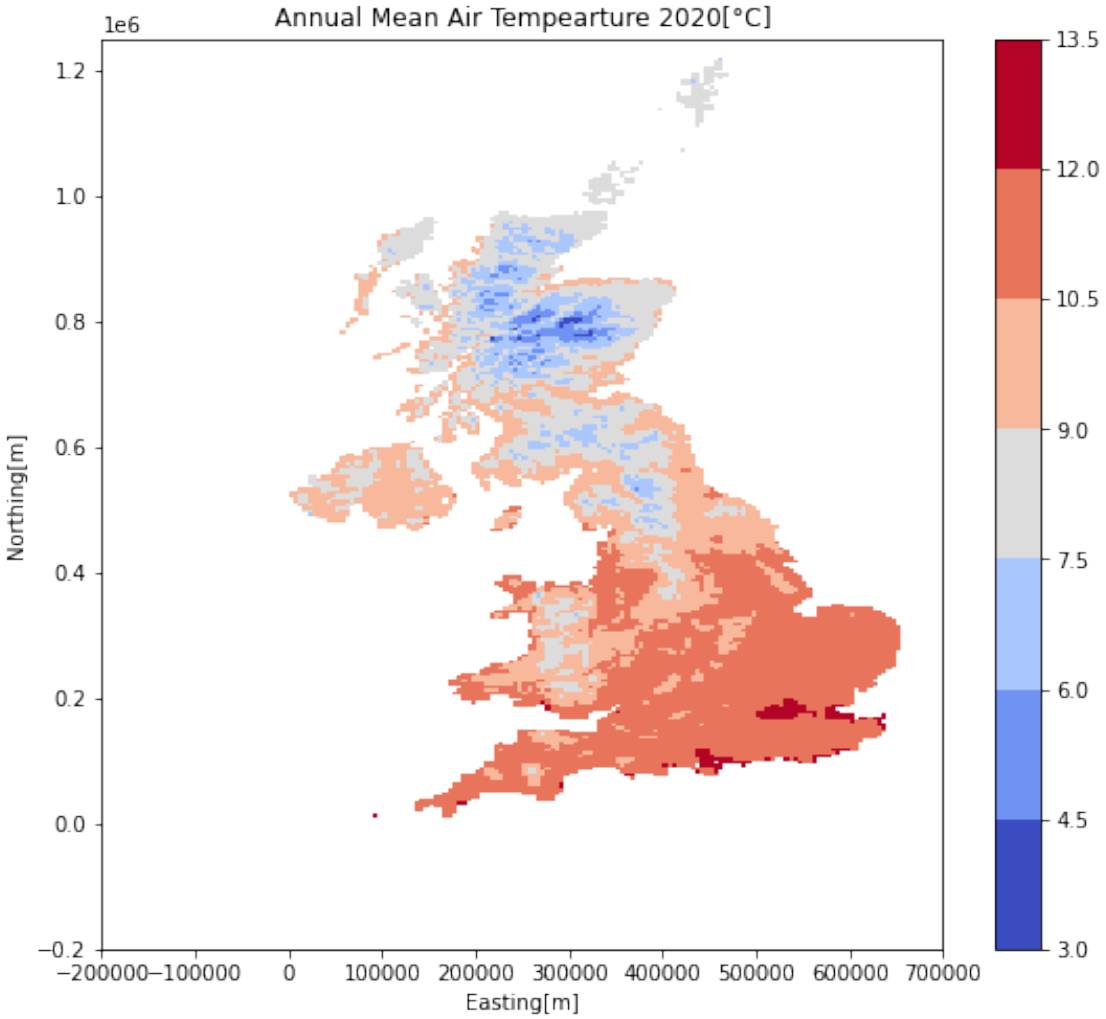
[ ]:
```
#mean airtemp 1976
plt.figure(figsize=[9,8])
airplt1976 = airtemp_dat['tas'].sel(time='1976')
# color1= '#89CFF0'
# color2 = '#FF6E00'
```

```
airplt1976.plot(add_labels=False, levels = 10, cmap='coolwarm') #removing␣
 ↪xarray labels, changing colours
plt.title('Annual Mean Air Tempearture 1976[°C]')
plt.xlabel('Easting[m]')
plt.ylabel('Northing[m]')
plt.savefig('figures/Air 1976.png')
```

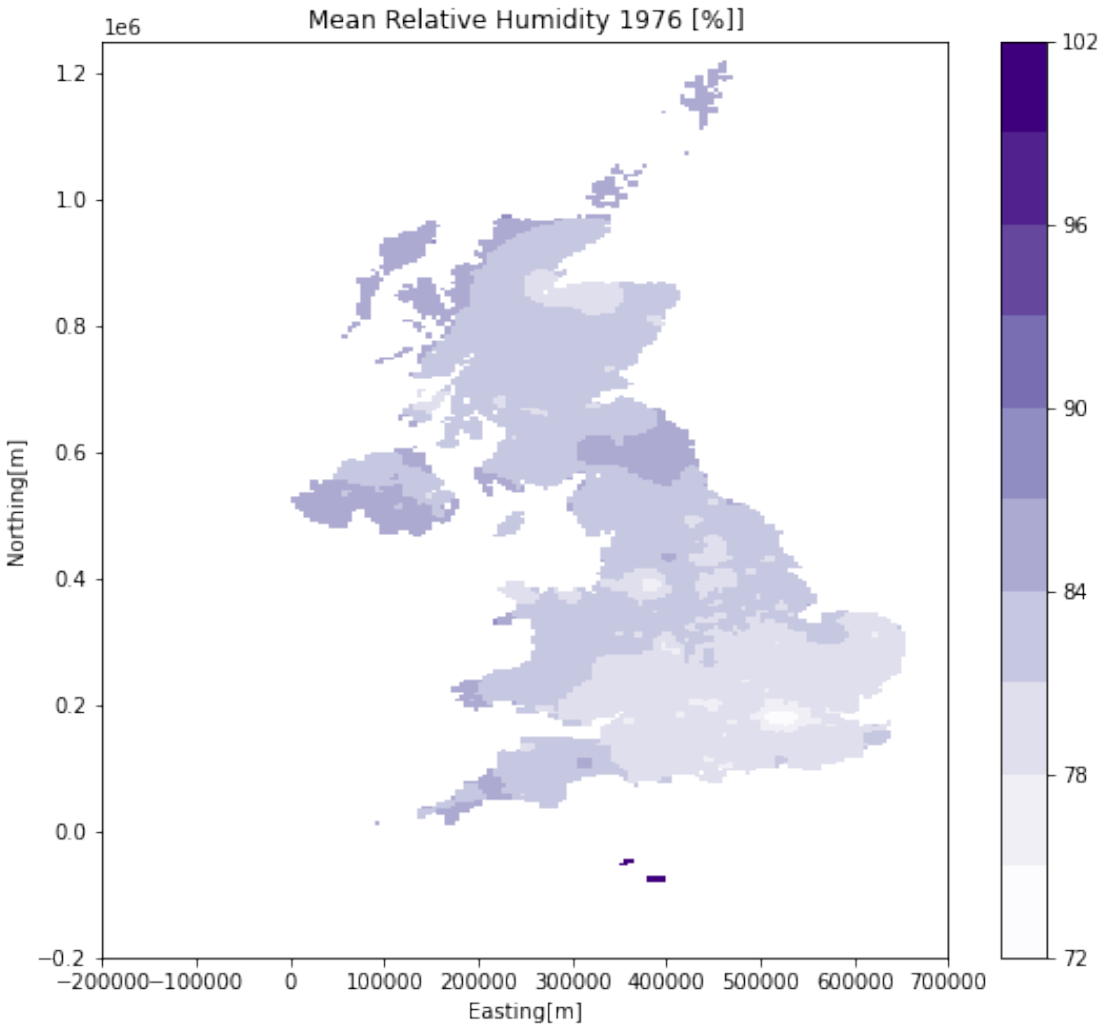


[ ]:
```
#mean airtemp 2020
plt.figure(figsize=[9,8])
airplt2020 = airtemp_dat['tas'].sel(time='2020')
airplt2020.plot(add_labels=False, levels = 10, cmap='coolwarm') #removing␣
 ↪xarray labels, changing colours for purpose
plt.title('Annual Mean Air Tempearture 2020[°C]')
plt.xlabel('Easting[m]')
```

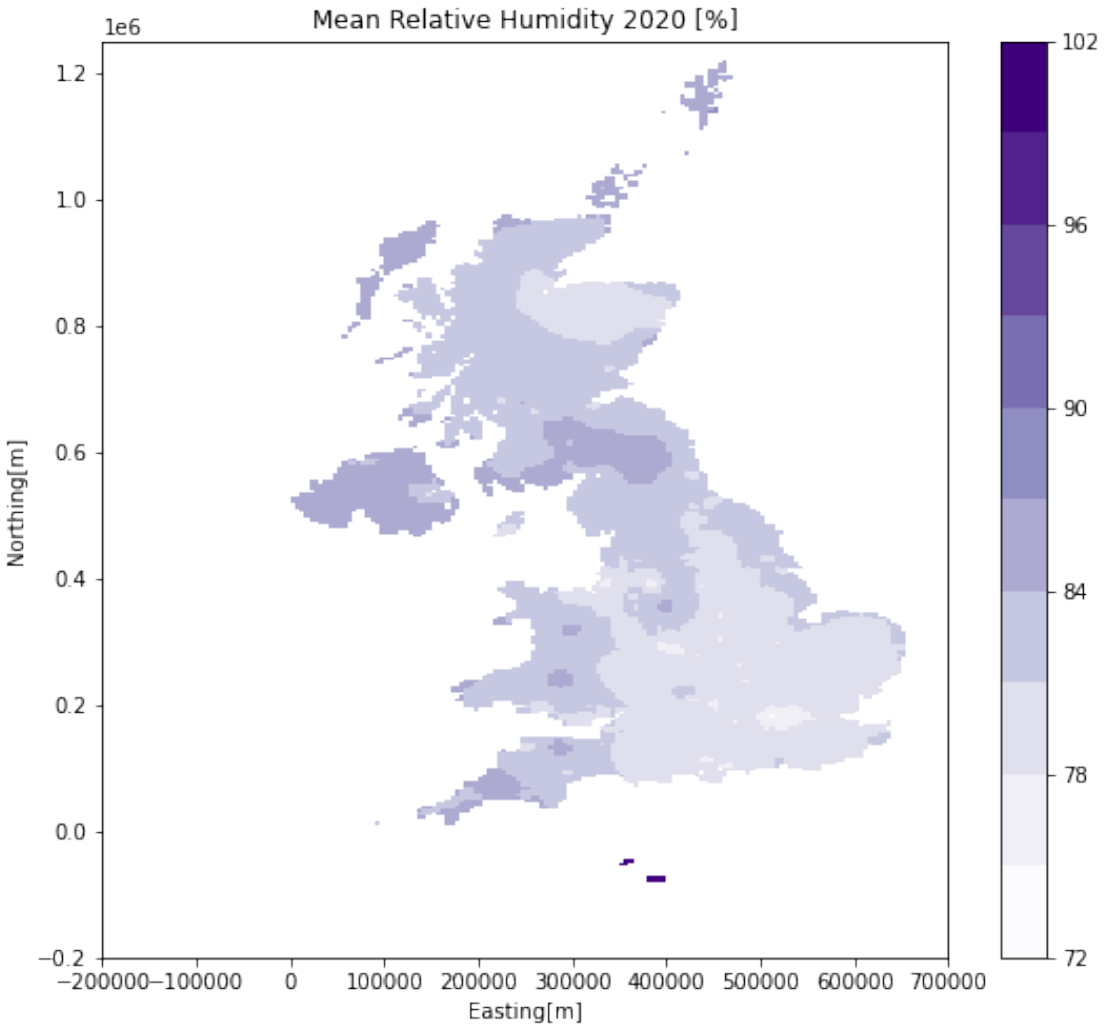
```
plt.ylabel('Northing[m]')
plt.savefig('figures/Air 2020.png')
```



[ ]:
```
#annual relative humidity 1976
plt.figure(figsize=[9,8])
humidplt1976 = humidity_dat['hurs'].sel(time='1976')
# color1= '#89CFF0'
# color2 = '#FF6E00'
humidplt1976.plot(add_labels=False, levels = 10, cmap='Purples') #removing␣
 ↪xarray labels, changing colours
plt.title('Mean Relative Humidity 1976 [%]]')
plt.xlabel('Easting[m]')
plt.ylabel('Northing[m]')
plt.savefig('figures/Humidity 1976.png')
```



[ ]:
```
plt.figure(figsize=[9,8])
humidplt2020 = humidity_dat['hurs'].sel(time='2020')
humidplt2020.plot(add_labels=False, levels = 10, cmap='Purples') #removing␣
 ↪xarray labels, changing colours
plt.title('Mean Relative Humidity 2020 [%]')
plt.xlabel('Easting[m]')
plt.ylabel('Northing[m]')
plt.savefig('figures/Humidity 2020.png')
```

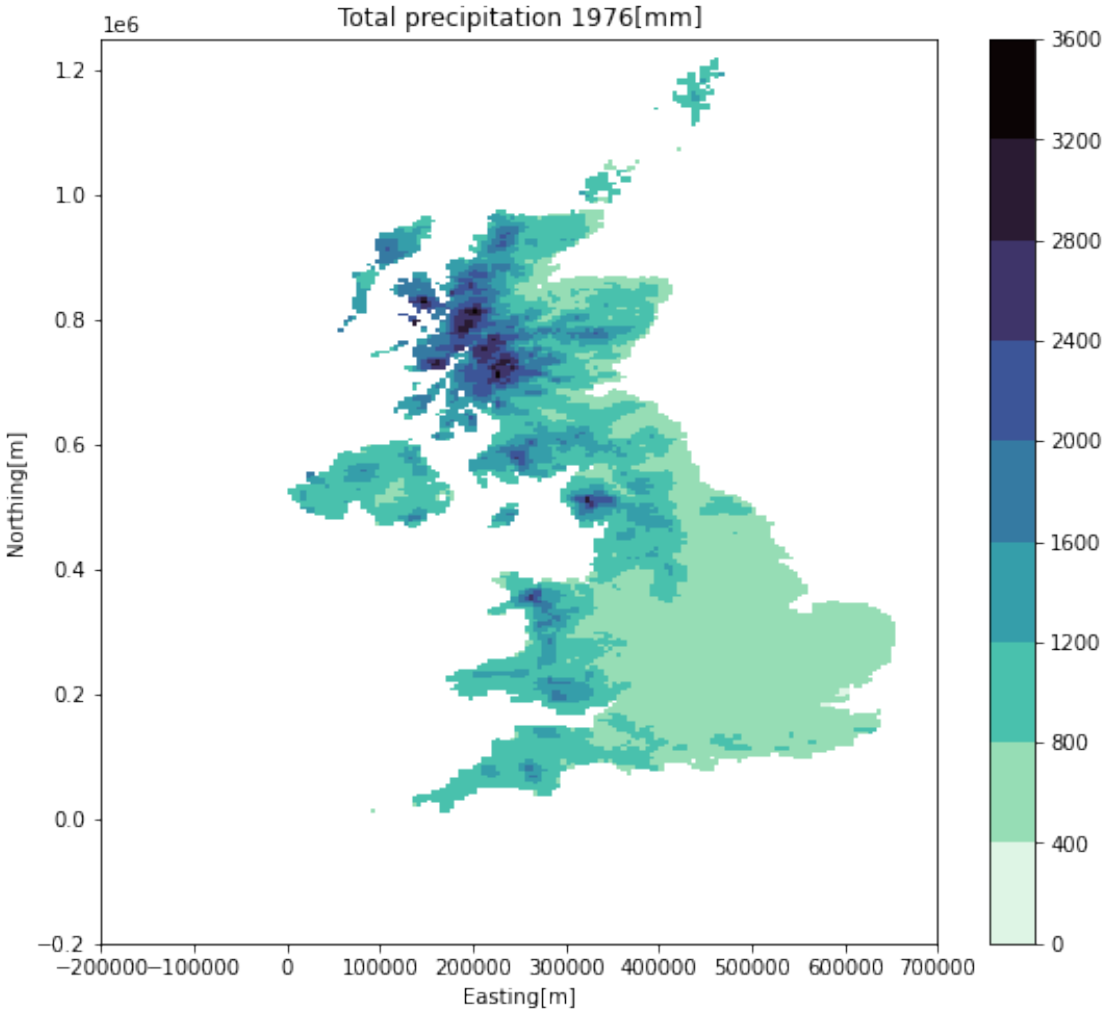


[ ]:
```
print(humidplt1976.to_masked_array().mean())
print(humidplt2020.to_masked_array().mean())
```

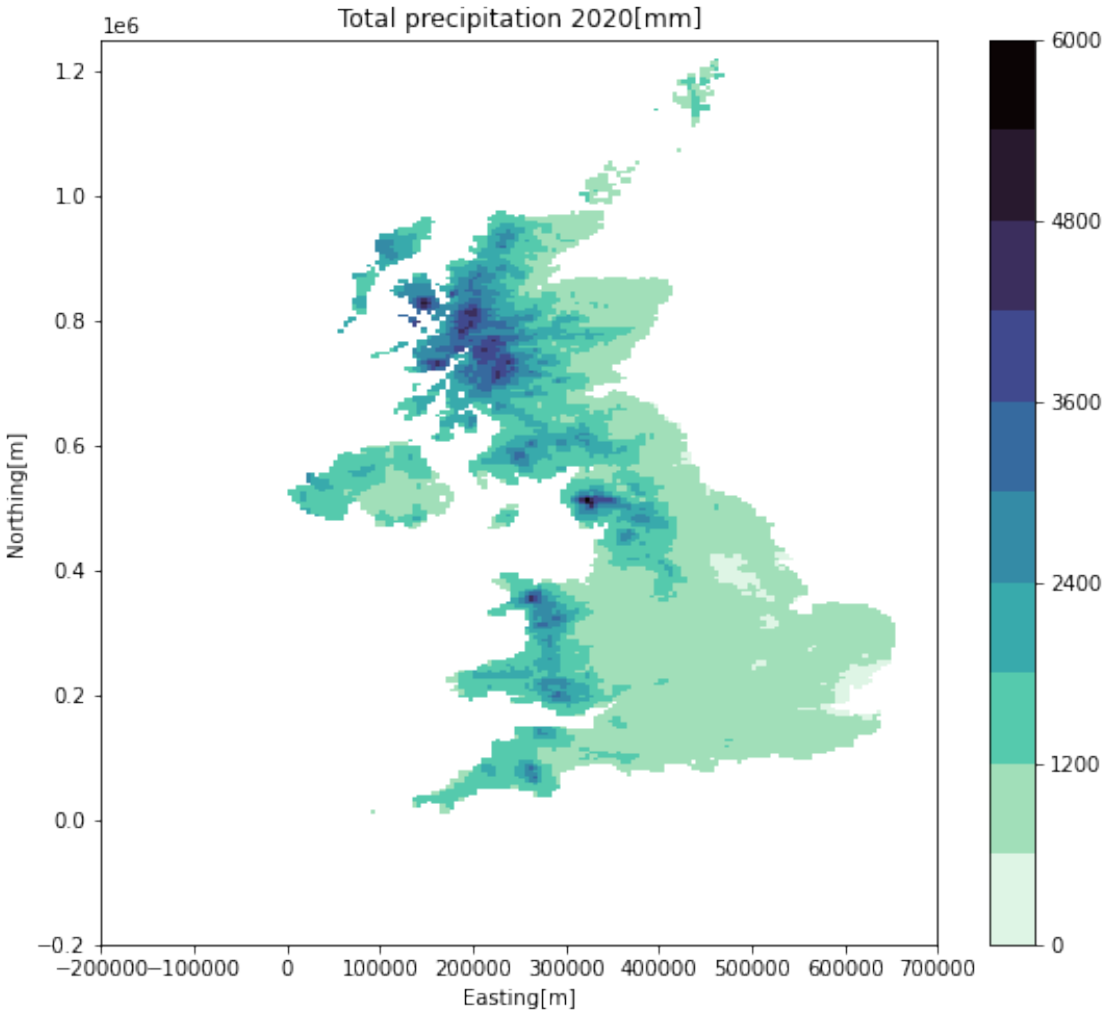
```
81.96404646417585
81.91124372868984
```

[ ]:
```
plt.figure(figsize=[9,8])
rainplt1976 = rainfall_dat['rainfall'].sel(time='1976')
# color1= '#89CFF0'
# color2 = '#FF6E00'
rainplt1976.plot(add_labels=False, levels = 10, cmap='mako_r') #removing xarray␣
 ↪labels, changing colours
plt.title('Total precipitation 1976[mm]')
plt.xlabel('Easting[m]')
plt.ylabel('Northing[m]')
```

```
plt.savefig('figures/Rainfall 1976.png')
```



[ ]:
```
plt.figure(figsize=[9,8])
rainplt2020 = rainfall_dat['rainfall'].sel(time='2020')
# color1= '#89CFF0'
# color2 = '#FF6E00'
rainplt2020.plot(add_labels=False, levels = 10, cmap='mako_r') #removing xarray␣
 ↪labels, changing colours
plt.title('Total precipitation 2020[mm]')
plt.xlabel('Easting[m]')
plt.ylabel('Northing[m]')
plt.savefig('figures/Rainfall 2020.png')
```



[ ]:
```
print(rainplt1976.to_masked_array().mean())
print(rainplt2020.to_masked_array().mean())
```

```
980.0606885748759
1340.510817572505
```

[ ]:
```
#creating dataframe consisting of climatic variables, total site index, species␣
 ↪richness for each site each year
df1 = indices_climate.groupby(by = ['Site Number', 'YEAR'])['SPECIES CODE'].
 ↪count().reset_index()
df2 = indices_climate.groupby(by = ['Site Number', 'YEAR'])['SITE INDEX'].sum().
 ↪reset_index()

df2 = df1.merge(df2)
```

```
df2.rename(columns={'SPECIES CODE':'SPECIES RICHNESS', 'SITE INDEX':'TOTAL SITE␣
 ↪INDEX'}, inplace=True)

# print(df2.shape)
# print(df2)
df1 = indices_climate.merge(df2)
# print(df1)
```

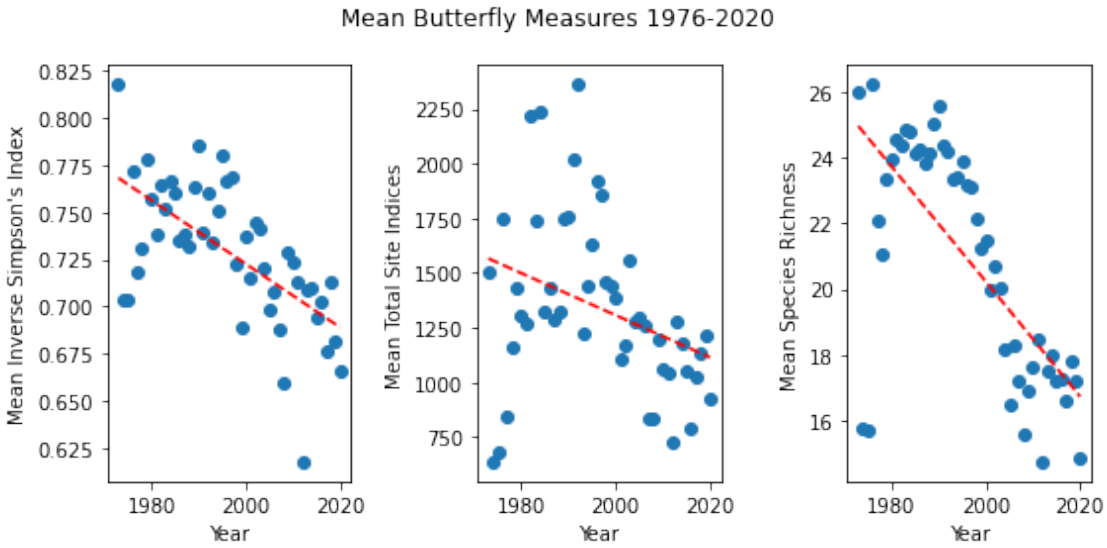
[ ]:
```
def calculate_simpson_diversity(df,sitenum,year):
    '''Calculates simpson's diversity index for a site in a specified year'''
    df1 = df[(df['YEAR'] == year) & (df['Site Number'] == sitenum)].copy()
    df1.reset_index(inplace=True)
    nlist = []
    for i in df1.index:
        x = df1['SITE INDEX'][i]
        nlist.append((x-1)*x)
    total = df1['TOTAL SITE INDEX'][0]
    totalb = total*(total-1)
    totala = sum(nlist)
    D = 1 - (totala/totalb)
    return D
```

[ ]:
```
# df3 = deepcopy(df1)
# df3['Simpsons Index']= df3.apply(lambda row: calculate_simpson_diversity(df3,␣
 ↪row['Site Number'], row['YEAR']), axis = 1)
#df3.tocsv(siteindices_biodiver)
```

[ ]:
```
# Merging dataframe with simpsons indices to per site per year data, savign as␣
 ↪csv for future use

# bio_clim =pd.merge(df2, df3, how='left', left_on=['Site Number','YEAR'],␣
 ↪right_on=['Site Number','YEAR'])
# bio_clim.drop_duplicates(keep='first',inplace=True) #dropping duplicate rows
# bio_clim.reset_index(inplace=True) #resetting index
# bio_clim.drop(columns=bio_clim.columns[0], axis=1, inplace=True) #dropping␣
 ↪extra index column
# # bio_clim.to_csv('bioD_clim_site_year')
bio_clim = pd.read_csv('bioD_clim_site_year') #loading csv created above
```

[ ]:
```
avgs = bio_clim.groupby('YEAR').mean().reset_index()
avgs.drop(['Easting','Northing','sun','average temp','rainfall','relative␣
 ↪humidity'], inplace=True, axis=1)

fig,axes =plt.subplots(ncols=3,figsize=(8,4))
axes[0].scatter(avgs['YEAR'],avgs['Simpsons Index'])
axes[1].scatter(avgs['YEAR'],avgs['TOTAL SITE INDEX'])
```

```
axes[2].scatter(avgs['YEAR'],avgs['SPECIES RICHNESS'])

z1 = np.polyfit(avgs['YEAR'],avgs['Simpsons Index'],1)
p1 = np.poly1d(z1)
axes[0].plot(avgs['YEAR'],p1(avgs['YEAR']),'r--')

z2 = np.polyfit(avgs['YEAR'],avgs['TOTAL SITE INDEX'],1)
p2 = np.poly1d(z2)
axes[1].plot(avgs['YEAR'],p2(avgs['YEAR']),'r--')

z3 = np.polyfit(avgs['YEAR'],avgs['SPECIES RICHNESS'],1)
p3 = np.poly1d(z3)
axes[2].plot(avgs['YEAR'],p3(avgs['YEAR']),'r--')

axes[0].set(ylabel="Mean Inverse Simpson's Index",xlabel='Year')
axes[1].set(ylabel='Mean Total Site Indices',xlabel='Year')
axes[2].set(ylabel='Mean Species Richness',xlabel='Year')
fig.suptitle('Mean Butterfly Measures 1976-2020')
fig.tight_layout()
fig.savefig('figures/Mean Measures.png')
```



[ ]:
```
bio_clim.dropna(inplace=True)
bio_clim.drop(bio_clim.columns[0],axis =1, inplace=True)
bio_clim['Diversity'] = np.select([bio_clim['Simpsons Index'] >= 0.66,␣
 ↪bio_clim['Simpsons Index'] <= 0.33],['High','Low'],default='Medium')␣
 ↪#categorising sites in each year into 'low/medium/high' diversity
```

[ ]:
```
site_location = pd.read_csv('final_ukbmssitelocationdata2020.
 ↪csv',encoding='cp1252')
bio_clim_latlong =pd.merge(bio_clim, site_location[['Site␣
 ↪Number','latitude','longitude']], how='left', left_on=['Site Number'],␣
 ↪right_on=['Site Number']) #adding site location latitude and longitude to␣
 ↪final dataset
# bio_clim_latlong.to_csv('BioD_year_site_latlong.csv')
bio_clim_latlong
```

[ ]:

	Site Number	YEAR	SPECIES RICHNESS	TOTAL SITE INDEX	COUNTRY	\
0	1	1976	27	798	England	
1	1	1977	28	413	England	
2	1	1978	27	857	England	
3	1	1979	27	825	England	
4	1	1980	27	911	England	
…	…	…	…	…	…	
24553	5706	2020	15	796	England	
24554	5707	2020	14	3070	England	
24555	5708	2020	13	1507	England	
24556	5709	2020	18	1343	England	
24557	9002	2002	3	51	England	

	Easting	Northing	sun	average temp	rainfall	\
0	521000.0	281000.0	1501.819509	9.953381	488.571987	
1	521000.0	281000.0	1343.662376	9.526488	494.270350	
2	521000.0	281000.0	1288.404486	9.407102	523.350323	
3	521000.0	281000.0	1377.842541	9.009214	560.583337	
4	521000.0	281000.0	1377.842541	9.009214	636.268119	
…	…	…	…	…	…	
24553	420800.0	376000.0	1486.724707	9.134446	1264.091079	
24554	406700.0	371200.0	1382.917646	8.727352	1713.559597	
24555	427200.0	315700.0	1557.146589	10.361915	934.172339	
24556	427800.0	316800.0	1557.146589	10.361915	934.172339	
24557	248400.0	70300.0	1419.537168	10.780422	1205.736074	

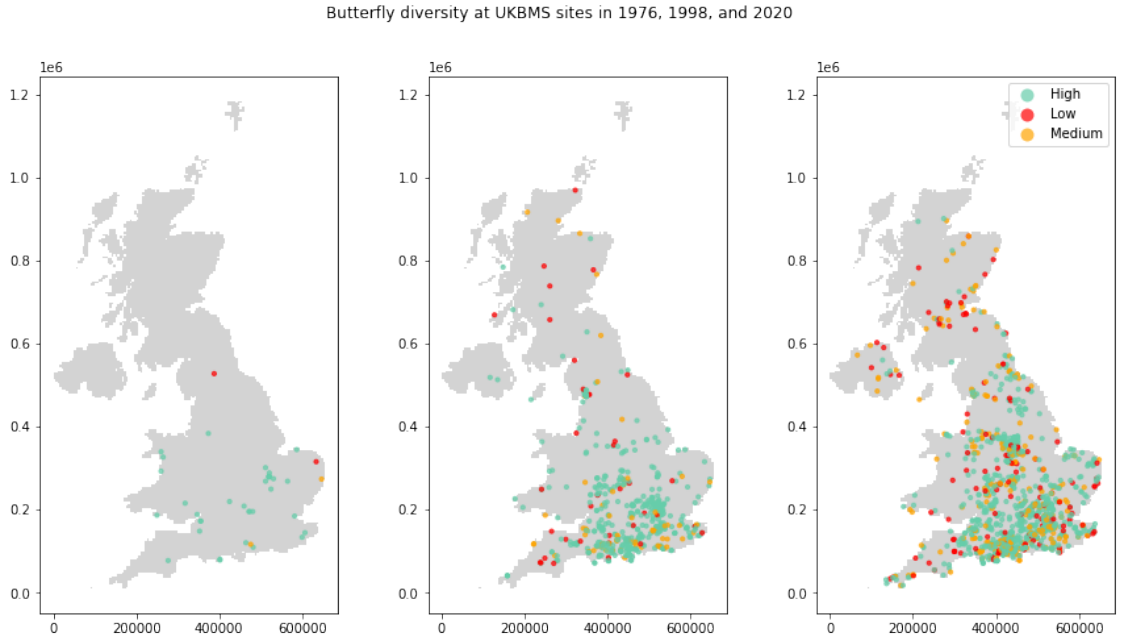
	relative humidity	Simpsons Index	Diversity	latitude	longitude
0	81.285496	0.779181	High	52.413625	-0.222413
1	83.330676	0.738111	High	52.413625	-0.222413
2	84.013799	0.801127	High	52.413625	-0.222413
3	83.049021	0.827729	High	52.413625	-0.222413
4	83.049021	0.827968	High	52.413625	-0.222413
…	…	…	…	…	…
24553	83.358684	0.848219	High	53.280572	-1.689506
24554	83.611149	0.794148	High	53.237789	-1.901073
24555	81.763461	0.854101	High	52.738252	-1.598579
24556	81.763461	0.887389	High	52.748110	-1.589600
24557	85.625346	0.580392	Medium	50.512809	-4.139556

```
[24558 rows x 15 columns]
```

[ ]:
```
#1997 ukbms, diversity high low etc on map
ukbms1976 = bio_clim_latlong[(bio_clim_latlong['YEAR'] == 1976)]
ukbms1998 = bio_clim_latlong[(bio_clim_latlong['YEAR'] == 1998)]

ukbms2020 = bio_clim_latlong[(bio_clim_latlong['YEAR'] == 2020)]

colors_dict = {'High':'green','Medium':'orange','Low':'red'}

ukmap = geopandas.read_file('uk_shpfiles/ukcp18-uk-land-5km.shp')
geometry = [shapely.geometry.Point(xy) for xy in zip(ukbms1976['Easting'],␣
 ↪ukbms1976['Northing'])]
geometry1998 = [shapely.geometry.Point(xy) for xy in zip(ukbms1998['Easting'],␣
 ↪ukbms1998['Northing'])]
geometry2020 = [shapely.geometry.Point(xy) for xy in zip(ukbms2020['Easting'],␣
 ↪ukbms2020['Northing'])]
crs = {'init':'epsg:27700'}
gdf1976 = geopandas.GeoDataFrame(ukbms1976,crs=crs,geometry=geometry)
gdf1998 = geopandas.GeoDataFrame(ukbms1998,crs=crs,geometry=geometry1998)
gdf2020 = geopandas.GeoDataFrame(ukbms2020,crs=crs,geometry=geometry2020)

fig, (ax1,ax2,ax3) = plt.subplots(nrows=1,ncols=3,figsize=(15,7.5))
ukmap.plot(ax=ax1,color='lightgrey')
ukmap.plot(ax=ax2,color='lightgrey')
ukmap.plot(ax=ax3,color='lightgrey')
ax1 = gdf1976.plot(ax=ax1,column='Diversity',legend=False, cmap=colors.
 ↪ListedColormap(['mediumaquamarine','Red','Orange']),alpha=0.7,markersize=10)

ax1 = gdf1998.plot(ax=ax2,column='Diversity',legend=False, cmap=colors.
 ↪ListedColormap(['mediumaquamarine','Red','Orange']),alpha=0.7,markersize=10)

ax3 = gdf2020.plot(ax=ax3,column='Diversity',legend=True, cmap=colors.
 ↪ListedColormap(['mediumaquamarine','Red','Orange']),alpha=0.7,markersize=10)

plt.suptitle('Butterfly diversity at UKBMS sites in 1976, 1998, and 2020')
plt.savefig('figures/butterflyDiv.png')
```

```
/Library/Frameworks/Python.framework/Versions/3.9/lib/python3.9/site-
packages/pyproj/crs/crs.py:130: FutureWarning: '+init=<authority>:<code>' syntax
is deprecated. '<authority>:<code>' is the preferred initialization method. When
making the change, be mindful of axis order changes:
https://pyproj4.github.io/pyproj/stable/gotchas.html#axis-order-changes-in-
proj-6
  in_crs_string = _prepare_from_proj_string(in_crs_string)
/Library/Frameworks/Python.framework/Versions/3.9/lib/python3.9/site-
```

```
packages/pyproj/crs/crs.py:130: FutureWarning: '+init=<authority>:<code>' syntax
is deprecated. '<authority>:<code>' is the preferred initialization method. When
making the change, be mindful of axis order changes:
https://pyproj4.github.io/pyproj/stable/gotchas.html#axis-order-changes-in-
proj-6
  in_crs_string = _prepare_from_proj_string(in_crs_string)
/Library/Frameworks/Python.framework/Versions/3.9/lib/python3.9/site-
packages/pyproj/crs/crs.py:130: FutureWarning: '+init=<authority>:<code>' syntax
is deprecated. '<authority>:<code>' is the preferred initialization method. When
making the change, be mindful of axis order changes:
https://pyproj4.github.io/pyproj/stable/gotchas.html#axis-order-changes-in-
proj-6
  in_crs_string = _prepare_from_proj_string(in_crs_string)
```



[ ]:
```
low_1976 = ukbms1976[(ukbms1976['Diversity'] == 'Low')].count()
low_1998 = ukbms1998[(ukbms1998['Diversity'] == 'Low')].count()
low_2020 = ukbms2020[(ukbms2020['Diversity'] == 'Low')].count()

print('low % 1976:',(low_1976['Diversity']/len(ukbms1976['Diversity'])*100))
print('low % 1998:',(low_1998['Diversity']/len(ukbms1998['Diversity'])*100))
print('low % 2020:',(low_2020['Diversity']/len(ukbms2020['Diversity'])*100))


medium_1976 = ukbms1976[(ukbms1976['Diversity'] == 'Medium')].count()
medium_1998 = ukbms1998[(ukbms1998['Diversity'] == 'Medium')].count()
medium_2020 = ukbms2020[(ukbms2020['Diversity'] == 'Medium')].count()
```

```
print('medium % 1976:',(medium_1976['Diversity']/
  ↪len(ukbms1976['Diversity'])*100))
print('medium % 1998:',(medium_1998['Diversity']/
  ↪len(ukbms1998['Diversity'])*100))
print('medium % 2020:',(medium_2020['Diversity']/
  ↪len(ukbms2020['Diversity'])*100))
```

```
low % 1976: 5.263157894736842
low % 1998: 7.326732673267326
low % 2020: 11.409395973154362
medium % 1976: 5.263157894736842
medium % 1998: 14.653465346534652
medium % 2020: 20.385906040268456
```