Reserach Question: How does the level of greenhouse gases and particulate matter in the atmosphere affect the levels of fog in Delhi?

In [ ]:
```
#making necessary imports
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import matplotlib.cm as cm
import matplotlib.colors as colors
```

In [2]:
```
#Datasets gathered from Kaggle

air_quality = pd.read_csv("city_day.csv") #https://www.kaggle.com/rohanrao/air-quality-data-in-india
weather_delhi = pd.read_csv("testset.csv") #https://www.kaggle.com/mahirkukreja/delhi-weather-data
```

In [3]:
```
#making necessary conversions and cleaning the data

weather_delhi["datetime_utc"] = pd.to_datetime(weather_delhi["datetime_utc"])
air_quality_delhi = air_quality[air_quality["City"] == "Delhi"]
air_quality_delhi =air_quality_delhi[air_quality_delhi["Date"] <= "2017-01-01"]
weather_delhi = weather_delhi[weather_delhi["datetime_utc"] >= "2015-01-01"]
weather_delhi = weather_delhi[weather_delhi["datetime_utc"] <= "2017-01-01"]
```

In [4]:
```
#Visualizing air quality data

air_quality_delhi.head()
```

Out[4]:

	City	Date	PM2.5	PM10	NO	NO2	NOx	NH3	CO	SO2	O3	Benzene	Toluene	Xylene	AQI	AQI_Bucket
10229	Delhi	2015-01-01	313.22	607.98	69.16	36.39	110.59	33.85	15.20	9.25	41.68	14.36	24.86	9.84	472.0	Severe
10230	Delhi	2015-01-02	186.18	269.55	62.09	32.87	88.14	31.83	9.54	6.65	29.97	10.55	20.09	4.29	454.0	Severe
10231	Delhi	2015-01-03	87.18	131.90	25.73	30.31	47.95	69.55	10.61	2.65	19.71	3.91	10.23	1.99	143.0	Moderate
10232	Delhi	2015-01-04	151.84	241.84	25.01	36.91	48.62	130.36	11.54	4.63	25.36	4.26	9.71	3.34	319.0	Very Poor
10233	Delhi	2015-01-05	146.60	219.13	14.01	34.92	38.25	122.88	9.20	3.33	23.20	2.80	6.21	2.96	325.0	Very Poor

In [5]:
```
#Visualizing weather data

weather_delhi.head()
```

Out[5]:

	datetime_utc	conds	dewptm	fog	hail	heatindexm	hum	precipm	pressurem	rain	snow	tempm	thunder	tornado	vism	wdird
90000	2015-01-01 00:00:00	Partial Fog	9.0	1	0	NaN	91.0	NaN	1016.0	0	0	10.0	0	0	0.5	NaN
90001	2015-01-01 03:00:00	Partial Fog	10.0	1	0	NaN	90.0	NaN	1018.0	0	0	11.0	0	0	0.5	NaN
90002	2015-01-01 06:00:00	Smoke	11.0	0	0	NaN	54.0	NaN	1019.0	0	0	18.0	0	0	1.0	NaN
90003	2015-01-01 09:00:00	Smoke	11.0	0	0	NaN	43.0	NaN	1016.0	0	0	21.0	0	0	1.0	340.0
90004	2015-01-01 12:00:00	Haze	12.0	0	0	NaN	54.0	NaN	1016.0	0	0	19.0	0	0	1.0	NaN

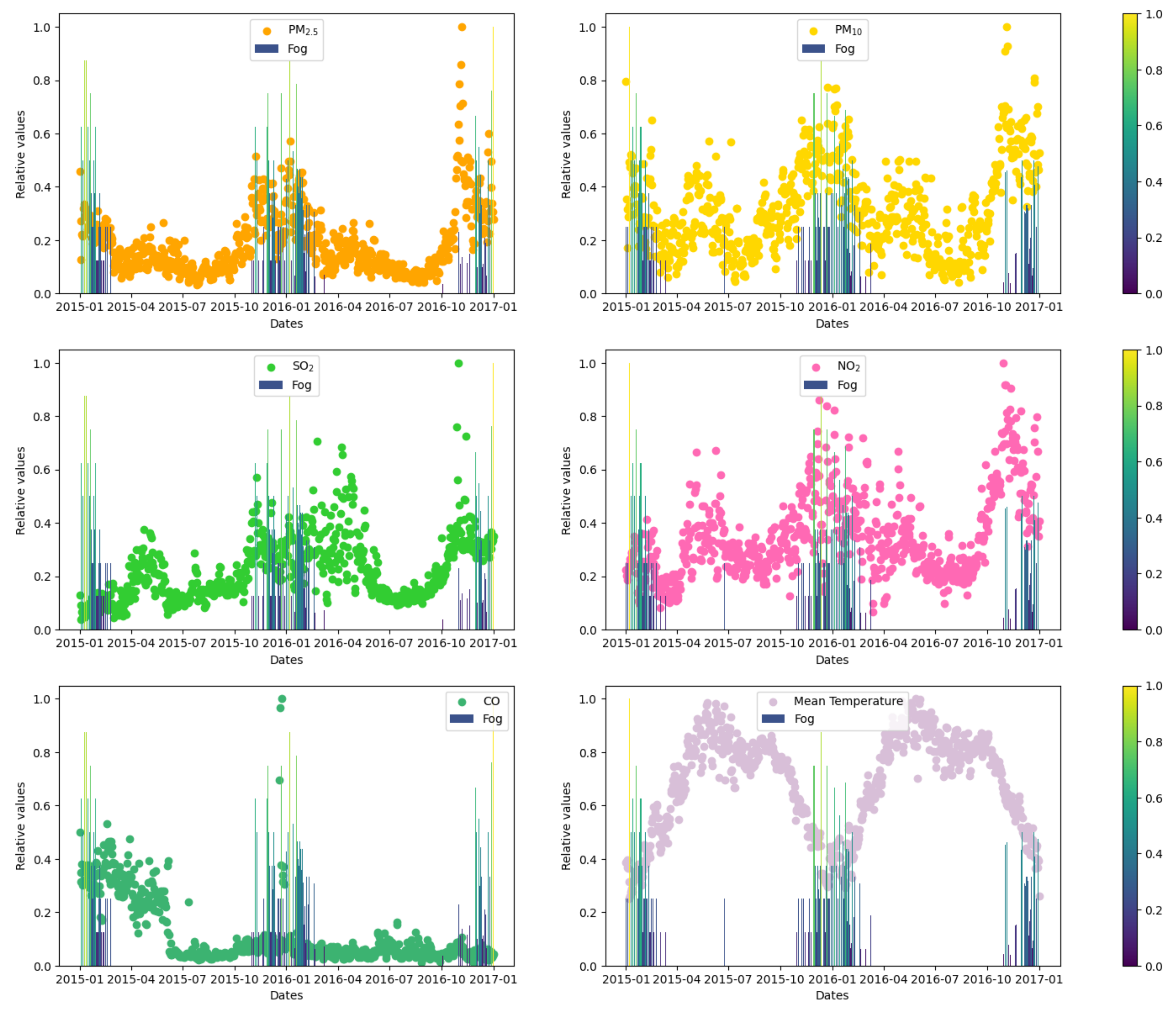
In [6]:
```
#since we don't require hourly data, we group the values by date and take the mean of all values for a single d

weather_delhi_final = weather_delhi.groupby(pd.Grouper(key = "datetime_utc", freq = 'D')).mean()
```

In [7]:
```
#range of dates over which we make our observations.

dates = np.array(pd.to_datetime(air_quality_delhi["Date"]))
```

In [8]:
```
#Quantity fog which is to be observed. Range is from 0 to 1

fog =  np.array(weather_delhi_final["fog"])
```

In [9]:
```
#We need to compare trends and the data indicates fog levels are between 0 and 1, therefore we require pollutan
#between 0 and 1. We divide each value with it's maximum, thus scaling them down
#Here, a ratio of 0 indicates a lower value and 1 indicates a higher value

mean_temp = np.array(weather_delhi_final["tempm"])
mean_temp = mean_temp/max(mean_temp)
pm25 = np.array(air_quality_delhi["PM2.5"])
pm25 = pm25/max(pm25)
pm10 = np.array(air_quality_delhi["PM10"])
pm10 = pm10/max(pm10)
so2 = np.array(air_quality_delhi["SO2"])
so2 = so2/max(so2)
no2 = np.array(air_quality_delhi["NO2"])
no2 = no2/max(no2)
co = np.array(air_quality_delhi["CO"])
co = co/max(co)
```

In [10]:
```
#making the subplots and plotting the data

fig, axs = plt.subplots(3, 2, figsize = (1920/100, 1500/100), dpi = 100)

cmap = cm.get_cmap('viridis')
cpick = cm.ScalarMappable(cmap=cmap, norm=colors.Normalize(vmin=0, vmax=1.0))
cpick.set_array([])

for i in axs:
    plt.colorbar(cpick, orientation = "vertical", ax = i)

axs[0, 0].bar(dates, fog, label = "Fog", color = cpick.to_rgba(fog))
axs[0, 0].scatter(dates, pm25, c = 'orange', label = "PM$_{2.5}$")
axs[0, 0].legend()
axs[0, 0].set_xlabel("Dates")
axs[0, 0].set_ylabel("Relative values")

axs[0, 1].bar(dates, fog, label = "Fog", color = cpick.to_rgba(fog))
axs[0, 1].scatter(dates, pm10, c = 'gold', label = "PM$_{10}$")
axs[0, 1].legend()
axs[0, 1].set_xlabel("Dates")
axs[0, 1].set_ylabel("Relative values")

axs[1, 0].bar(dates, fog, label = "Fog", color = cpick.to_rgba(fog))
axs[1, 0].scatter(dates, so2, c = 'limegreen', label = "SO$_{2}$")
axs[1, 0].legend()
axs[1, 0].set_xlabel("Dates")
axs[1, 0].set_ylabel("Relative values")

axs[1, 1].bar(dates, fog, label = "Fog", color = cpick.to_rgba(fog))
axs[1, 1].scatter(dates, no2, c = 'hotpink', label = "NO$_{2}$")
axs[1, 1].legend()
axs[1, 1].set_xlabel("Dates")
axs[1, 1].set_ylabel("Relative values")

axs[2, 0].bar(dates, fog, label = "Fog", color = cpick.to_rgba(fog))
axs[2, 0].scatter(dates, co, c = 'mediumseagreen', label = "CO")
axs[2, 0].legend()
axs[2, 0].set_xlabel("Dates")
axs[2, 0].set_ylabel("Relative values")

axs[2, 1].bar(dates, fog, label = "Fog", color = cpick.to_rgba(fog))
axs[2, 1].scatter(dates, mean_temp, c = 'thistle', label = "Mean Temperature")
axs[2, 1].legend()
axs[2, 1].set_xlabel("Dates")
axs[2, 1].set_ylabel("Relative values")

fig.savefig('Assignment4.jpeg', edgecolor = 'black', dpi = 1000, transparent=True)
```



My visual showcases 6 different factors which have been investigated to address the research problem of determining the fog levels in a region. All these 6 factors lead us to interesting conclusions. In order to understand the results, we must understand fog formation. In order for fog to form, dust or some kind of air pollution needs to be present in the air. Water vapor condenses around these microscopic solid particles, leading to fog formation. Depending on the temperature, fog can form very suddenly and then disappear just as quickly. A scientific method to use is to normalize the values to lie between 0 and 1, with 0 indicating a low value and 1 indicating a higher value, so as the comparisons become easier and the trends become observable. I have investigated particulates such as PM2.5, PM10, SO2, NO2, CO, and the mean temperature upon the fog levels every day over a period of 2 years from Jan 2015 – Jan 2017. From the first 2 visuals, it becomes quite evident that the beginning of every year sees a peak in the levels of PM2.5 and PM10, and these peaks lie in correlation with the fog levels as indicated by the bars. A similar trend can be observed for SO2 and NO2 as well. However, this is not the case for CO, as the graph shows no understandable correlations. This leads us to the conclusion that the larger diameter of the particles around which the water can condense (such as in PM2.5, PM10, SO2, NO2), the greater the fog formation. CO being a relatively smaller molecule has little to no contribution towards fog formation with no observable trends. Another conclusion from the visuals is that the lower the mean temperature for a day, the greater the formation of fog is. Every year, December and January are periods of winter during which there are greater levels of fog formation as mean temperatures are low lying at an average of 10 °C and as summer approaches, the level of fog also decreases as the mean temperature of a day rises which can be inferred from the graph, and this can be verified practically as well. Therefore one can summarize the results by saying, to maintain the natural water cycle, one must lower the levels of these pollutants in the atmosphere.