CEE 263C – Weather and Storms
Final Report

Data Analysis of Miami and Los Angeles Weather (2010 – 2022)

Raghav Sharma
MS – Environmental Engineering
Department of Civil and Environmental Engineering

1. Introduction

Miami and Los Angeles are both massive urban centers and global cities on the East and West Coast of the United States of America, respectively. While both the cities share metropolitan characteristics, their contrasting physical/geographic features and climate make them interesting candidates for a comparative weather data analysis.

Los Angeles, the seat of the Los Angeles County in Southern California, is the second most populous city of the United States. Situated on a broad coastal plain between the Pacific and mountains, the city has a varied geographic entity. Nearly half of LA county is covered with mountain ranges with the San Gabriel and the San Bernadino mountains to the north and northeast.[1] The Los Angeles (LA) city which covers a large chunk of southern LA county, rises from the sea level at Venice Beach to Mount Lukens at about 1,550 meters above sea level. LA climate is classified as semi-arid or Mediterranean with a dry summer and a winter rainy season. While it has hot, dry summers and mild-to-warm winters associated with Mediterranean climate, annual precipitation is lower than typical. The arc of ranges surrounding the city protects it from the intense desert heat and cold from the east but render ideal conditions for the city's infamous photochemical smog[2]. The above-mentioned details are corroborated by the data analysis of temperature, rainfall and wind speeds presented in the later sections.

Miami, the county-seat of the Miami-Dade County in Florida, is situated on a broad coastal plain between the Everglades to the west and the Biscayne Bay to the east. Much low-lying when compared to Los Angeles, Miami has an average elevation of 6ft. Situated on the Atlantic coast of Florida, Miami's climate can be classified as tropical monsoon climate with hot, humid summers and short, warm winters. Miami's wet season begins during May and continues till mid-October accompanied by

[1] https://www.britannica.com/place/Los-Angeles-California/Landscape
[2] https://en.wikipedia.org/wiki/Climate_of_Los_Angeles

high humidity and afternoon thunderstorms. Miami receives one of the greatest annual precipitation among major US cities and reports thunders on about eighty days per year. Miami is also prone to hurricanes with an Atlantic Hurricane season that runs from June to late-November. Hurricane landfalls in Miami are most likely in mid-August through September, making it statistically the most likely major city in the world to be hit by a hurricane[3]. Some recent hurricanes to have hit Miami include Katrina and Wilma in 2005 and Irma in 2017.

In the following sections, a comprehensive data analysis of the historical daily weather data from 2010 onwards is presented. The weather data was obtained from National Ocean and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI)[4]. The upcoming data analysis section will explore and analyze temperature, precipitation, and wind data for the two cities from 2010-2022 and seek to investigate the differences in climate variables. Furthermore, we will also try to analyze LA air quality and hurricanes that have hit Miami since 2010. The air quality data was obtained from California Air Resources Board and South Coast Air Quality Management District, accessed via AQICN[5]. Additionally, we have also presented a comparison of Radiosonde data on December 03, 2022, accessed from University of Wyoming's weather portal[6] to conduct a comparative analysis of upper air variables in Miami and LA.

2. Data Description and Methodology

The weather dataset obtained from NCEI contains historical daily data from Jan 01, 2010 to Nov 27, 2022 for the following variables:

1. Average Temperature (Fahrenheit)
2. Minimum Temperature (Fahrenheit)
3. Maximum Temperature (Fahrenheit)
4. Precipitation (inches)
5. Average Wind Speed (knots)
6. Fastest 2-minute wind speed (knots)
7. Fastest 2-minute wind direction (degrees)

The air quality dataset for Los Angeles contains daily average of historical air pollutant concentrations from July 27, 2014, to Nov 3, 2022 for $PM_{2.5}$, PM_{10}, CO, NO_2, and O_3 from LA North-Main Street Station (ARB# 70087).

[3] https://en.wikipedia.org/wiki/Climate_of_Miami#Hurricanes
[4] https://www.ncei.noaa.gov/cdo-web/search
[5] https://aqicn.org/city/losangeles/los-angeles-north-main-street/m/
[6] https://weather.uwyo.edu/upperair/sounding.html

The sounding data contains data on the variation of Pressure (hPa), Temperature (C), Dew Point (C), Relative Humidity, Wind Speed, and Direction.

The time series data on weather variables and air quality was cleaned, formatted, analyzed and plotted using Python libraries NumPy, Pandas, Matplotlib, and Seaborn. The analysis approach was to analyze and compare temperature, precipitation, and wind speed data by considering daily, seasonal, and interannual, variations in the weather variables.

3. Data Analysis

3.1. Temperature

The average daily and monthly minimum and maximum temperature for Miami and Los Angeles have been plotted in the Figure 1.a and 1.b. Figures 1.c and 1.d present a boxplot of daily average temperatures by month, which help visualize the magnitude and variability of temperatures in each month in Miami and LA. From Figure 1, it can be easily concluded that Los Angeles experiences considerably cooler daily minimum and maximum temperatures than Miami. Figures 1a and 1b show that maximum temperatures in LA follow closely the minimum daily temperatures in Miami. August is the hottest month in both Miami and LA with maximum daily temperatures in August averaging in the 91.1°F in Miami and 84.5°F in Los Angeles. January is the coldest month in Miami while December being the coldest month in Los Angeles. Table 1 presents temperatures associated with the coldest and hottest months in Miami and Los Angeles.

The highest variability among daily average temperatures is observed in February in Los Angeles and January in Miami. The standard deviation of daily average temperatures in Los Angeles (7.57) is greater than that in Miami (6.80), meaning daily temperatures in LA are more variable than Miami on average. However, it is interesting to note that despite having a lower overall variability in temperatures, December, January, and February in Miami have significant variability in daily average temperature which can be inferred from the boxplot in Figure 1.c. This high variability in Winter is in contrast with the rainy months in Miami where temperatures are restricted to a narrow range due to the moderation in temperature associated with high precipitation and moisture. Another measure of temperature variation on a daily level is the difference between minimum and maximum temperature. Figure 2a presents a plot of the difference between minimum and maximum temperatures in Miami and Los Angeles. Figure 2a highlights and backs the fact that temperature range in Miami is restricted to a narrower range than Los Angeles. Maximum daily temperature range is greatest in November and lowest in May in Los Angeles. For Miami, January experiences the greatest temperature range and October the least. Figure 2b presents a negative correlation (R^2 = -0.91) between difference in average daily temperature range and precipitation in Miami, signifying that months with greatest average daily precipitation have a tighter daily temperature range.

Table 1. Average Maximum and Minimum Temperatures of Coldest and Hottest Months

City	Miami	Los Angeles
Coldest Month		
Month	*January*	*December*
Average Min Temp (°F)	61.3	48.5
Average Max Temp (°F)	76.6	67.6
Hottest Month		
Month	*August*	*August*
Average Min Temp (°F)	78.2	65.8
Average Max Temp (°F)	91.1	84.2

Figure 1. Variation in Min, Max and Average Daily Temperatures – Miami and Los Angeles

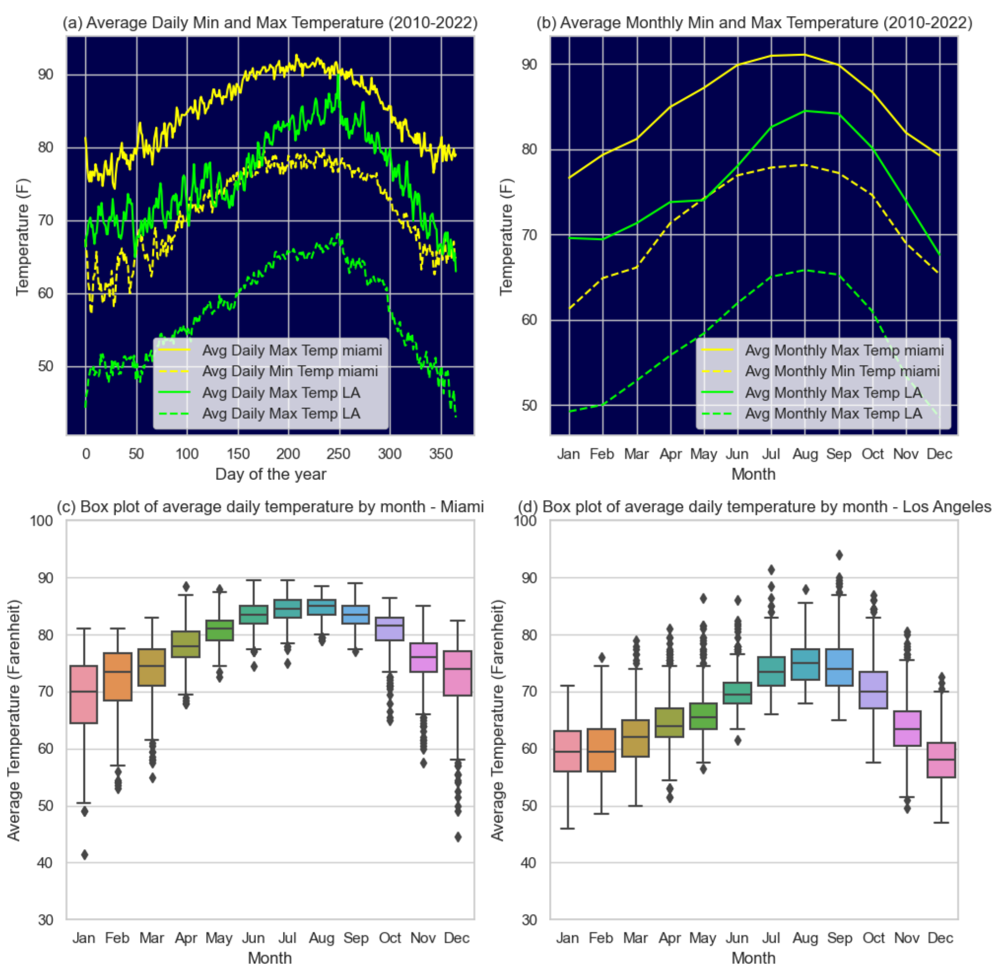
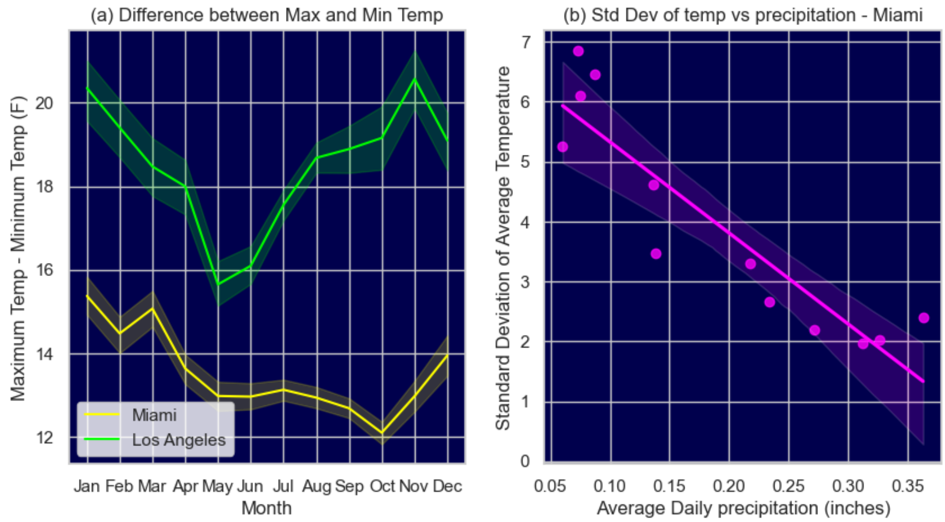


Figure 2. Analysis of average daily temperature range



3.2. Precipitation

The wet season in Miami begins in May and continues through mid-October, also facing a Hurricane season from August to November. Miami is one of the wettest major cities in the US, receiving about 62 inches of annual rainfall on average.[7] In contrast, most rainfall in Los Angeles occurs in the Winter, with the heaviest showers concentrated from late-November to March. Los Angeles is much drier in comparison to Miami with an annual average rainfall of just under 15 inches[7]. Heavy rainfall years in Los Angeles can be attributed to the storms associated with the Pineapple Express atmospheric river that brings moist air from Hawaii. Some cases of heavy rainfall due to the Pineapple Express in LA include the January 2005[8] and December 2010[9] storms. Both LA and Miami receive no snowfall. However, the largest recorded snow event in downtown LA was 2 inches on January 15, 1932[10]. The above-described rainfall scenarios in the two cities can be observed from the data analysis of daily precipitation data of our weather dataset (2010-2022). Figure 3a and 3b present total precipitation received in the thirteen-year period by month and the average number of rainy days by month for Miami and LA. Figure 4 presents the total monthly rainfall received by Miami and LA for all years in 2010-2022 through a heatmap. This visualization helps represent the general rainy season of the two cities and gives a great juxtaposition of the precipitation trends of Miami and LA.

From 3a, it can be concluded that from 2010-2022, June was the wettest month in Miami receiving 141.5 inches of rainfall in the thirteen years and average daily rainfall of 0.36 inches, followed by September (126.95 in and 0.33 in) and August (125.8 in and 0.31 in). In terms of average number of

---

[7] https://www.weather.gov/wrh/climate?wfo=mfl
[8] http://articles.latimes.com/2005/feb/25/local/me-soak25
[9] http://www.upi.com/Top_News/US/2010/12/22/S-Calif-storm-unleashes-torrent-of-rain/UPI-41611293008400/
[10] "We're Not in Kansas, but We Do Get Twisters – Los Angeles Times"

rainy days (Figure 3b), August leads with 19.6 days receiving precipitation on average, followed closely by July with 18.7. LA, in comparison is much drier receiving less than a sixth of the rainfall than Miami during the past thirteen years. December is the wettest month in LA, receiving 31.5 inches of rainfall over the 13-year period and an average daily precipitation of 0.11 inches, followed by January (31.52 in and 0.08 in). December also leads in the average number of rainy days in LA with 5.8 days/month on average. However, instead of January, March takes the second position in average number of rainy days at 4.9, tailgated by January at 4.8. The temperature moderation effect of precipitation has been discussed in the temperature section, greater precipitation and proximity to the ocean in Miami, helps restrict the temperatures to a narrow range as discussed before. Precipitation also results in lower daily average temperatures during the rainy season as presented in Table 2.

Table 2. Comparison of average daily temperatures on wet and dry days

Miami Rainy Season						
	May	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Avg Temp (Wet Days)	80.1	82.5	83.6	83.9	82.9	81.0
Avg Temp (Dry Days)	81.0	84.7	85.7	85.8	84.5	80.4
Los Angeles Rainy Season						
	Nov	**Dec**	**Jan**	**Feb**	**Mar**	
Avg Temp (Wet Days)	59.6	56.4	56.5	57.2	57.8	
Avg Temp (Dry Days)	64.1	58.5	59.9	60.2	62.9	

Figure 3. Monthly Precipitation Comparison

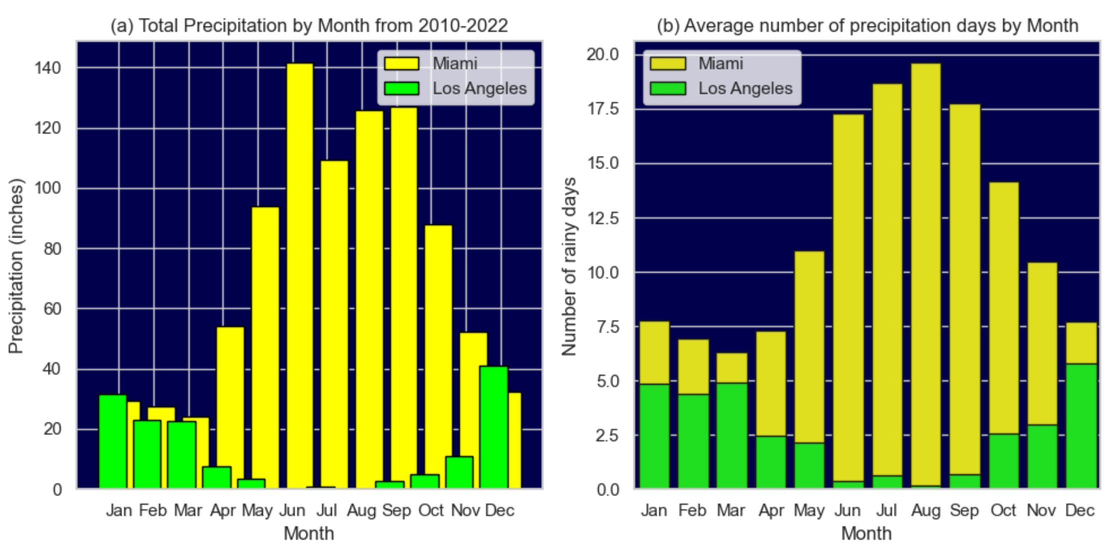


Figure 4. Total Monthly Precipitation (2010-2022)

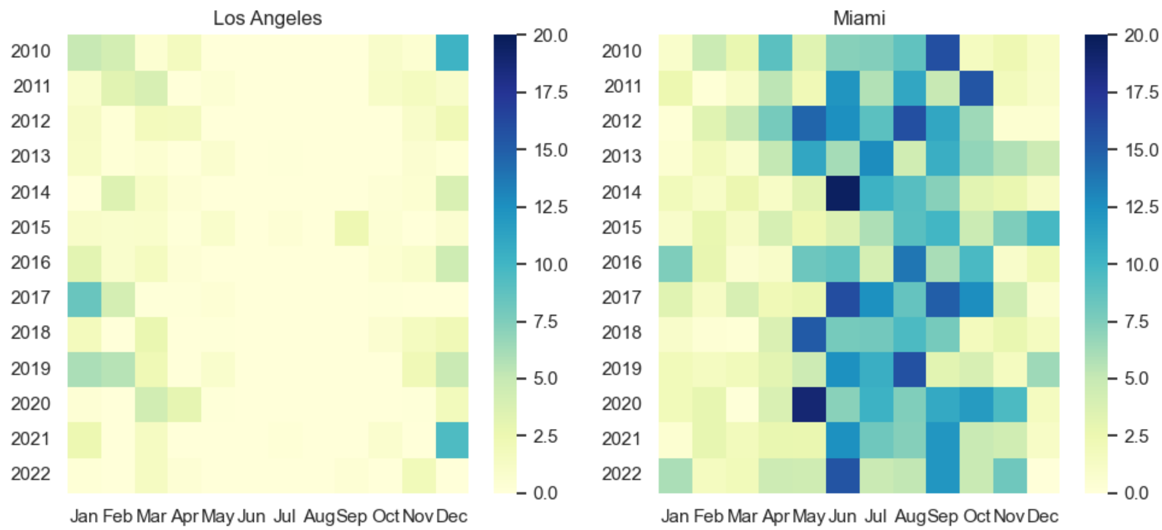
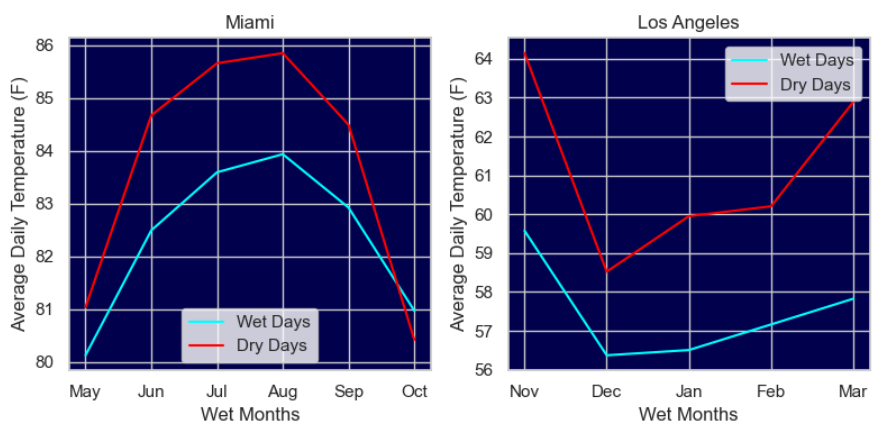


Figure 5. Average Temperature on Wet v/s Dry Days



3.3. Wind Speed and Hurricanes

Miami is by far windier than Los Angeles with an average wind speed of 7.7 knots in comparison to a meagre 1.6 knots, mainly due to fast straight-line winds associated with frequent afternoon thunderstorms in Miami coupled with an easterly sea breeze from the Atlantic. The windiest season in Miami is from October to May and June to September are relatively calmer months but not less windy by any measure in comparison to LA. Average wind direction of the fastest 2-minute wind in Miami is South-Easterly for all months except for January with northerly winds. In comparison, the average wind direction of the fastest 2-min wind in LA westerly with winds coming in from the Pacific. In Miami, May and April have the greatest average 2-min fastest wind of 18.6 knots. Fastest 2-min winds in LA are in April averaging at 10 knots.

Miami is also frequently battered with Hurricane winds. The impact to life and property from hurricanes in Miami is such that researchers and urban planners are rethinking the location of the city as a major urban hub, due to extensive inland inundation from extreme storm surge events from hurricane winds. As flood insurance premiums and real estate prices in Miami skyrocket with increasing flood risk from rising sea-levels, Miami faces inadvertent climate gentrification.[11]

The fastest 2-minute wind in the Miami dataset is 53 knots which occurred on the 10th of September 2017 when Hurricane Irma made landfall in Florida. Hurricane Irma was a category 5 hurricane on the Saffir-Simpson Hurricane Wind Scale. The average wind speed in Miami on this day was a staggering 39 knots. The most recent hurricane to have hit the coast of Florida was Nicole which was a rare November event (November 7, 2022- November 12, 2022) which followed just a month after Hurricane Ian (September 23, 2022 - October 2, 2022), a category 4 hurricane. Maximum 2-minute wind speed during Ian was 31.1 knots 28th September. Maximum 2-minute wind speed during Nicole was 22 knots on 10th November. Table 3 presents the maximum daily precipitation and fastest 2-min wind speed associated with recent hurricanes from the Miami dataset used in this analysis.

Table 3. Recent Hurricanes in Miami

Hurricane	Year	Dates	Max 1-day precipitation (in)	Fastest 2-min Wind Speed (knots)
Irma	2017	09/30 – 09/13	5.18	53
Sally	2020	09/10 – 09/15	1.75	31
Ian	2022	11/07 – 11/12	1.35	22
Nicole	2022	09/23 – 10/02	3.54	31

Figure 6.a plots average wind speed and wind direction by month for Miami and LA. Figure 6.b presents a boxplot of average wind speeds in Miami and LA giving a sense of the variability in average wind speeds. It can be inferred that the general wind direction in Miami is south-easterly compared to westerly in Los Angeles.

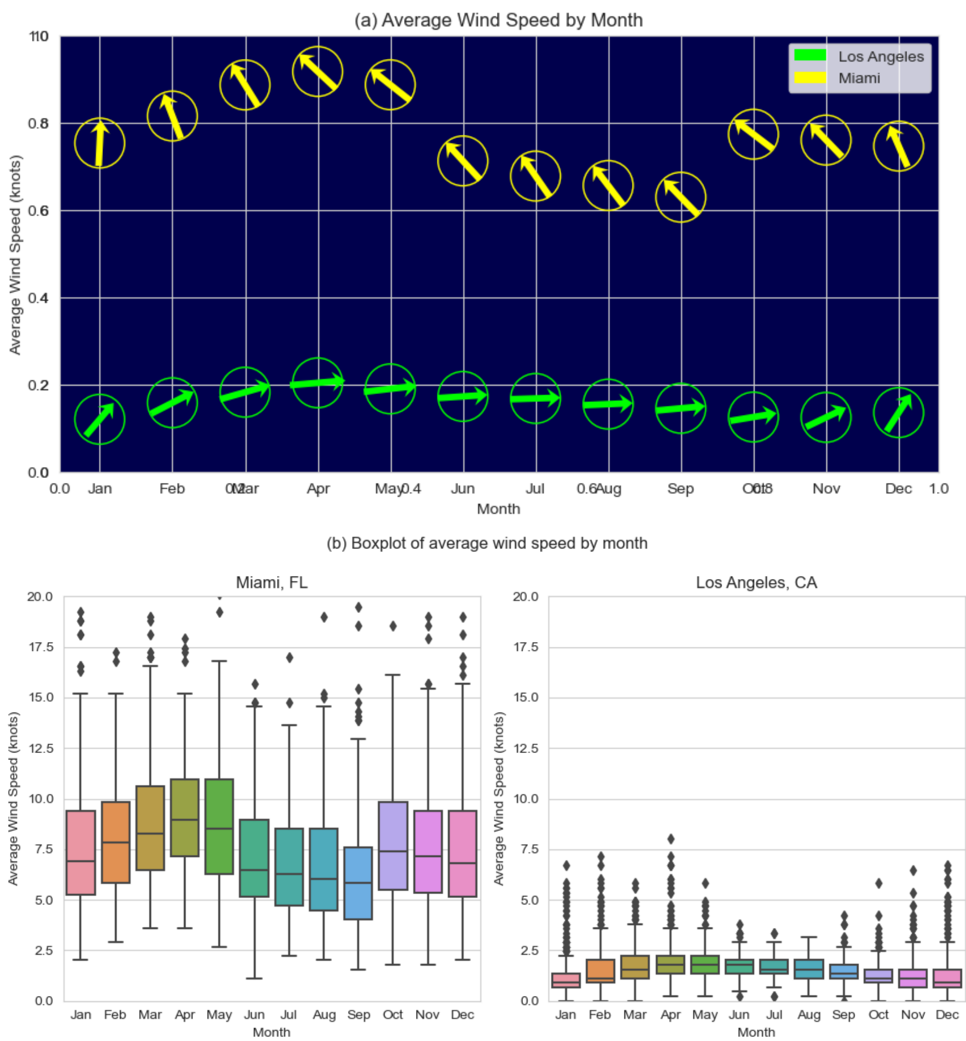
4. Sounding Data Analysis

The sounding data obtained from University of Wisconsin includes the Vandenberg station since radiosonde data from Los Angeles is not available. Sounding data is useful in analyzing the vertical extent of the atmosphere and study important features like the stability of the atmosphere and the presence of clouds by observing the variation of temperature, dew point, wind speed, and pressure

[11] Taylor, Z. J., & Aalbers, M. B. (2022). Climate gentrification: risk, rent, and restructuring in Greater Miami. *Annals of the American Association of Geographers*, *112*(6), 1685-1701. https://doi.org/10.1080/24694452.2021.2000358

with height. Atmospheric stability is important to determine the extent of vertical mixing of air pollutants which directly impacts visibility and particulate pollution. The sounding data is from the afternoon of December 3, 2022. Figure 7 presents the variation of temperature, dew point, and pressure with height. The pressure drops exponentially with height and starts dropping rapidly with increasing height in accordance with the Barometric pressure relationship.

Figure 6. Analysis of average wind speed and direction

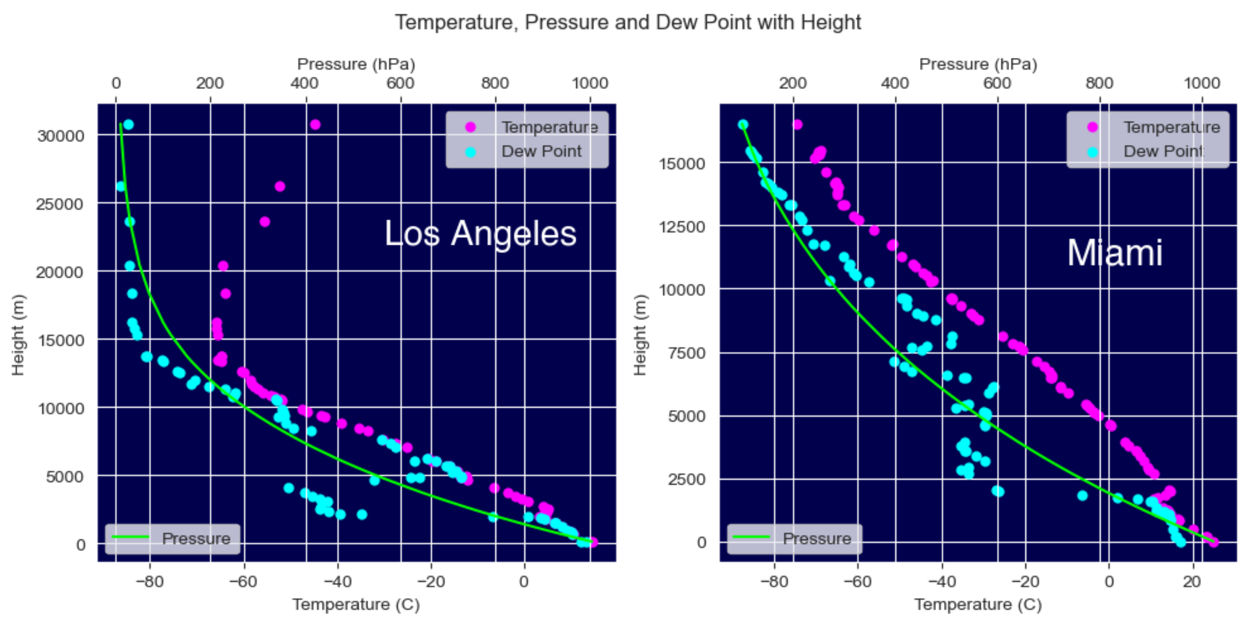


4.1. *Lapse rate, Stability, and Inversions*

In Miami, the temperature decreases with height till 1714m at a lapse rate of 7°C/km, implying that the atmosphere is conditionally unstable. From 1714m to 2156m, the lapse rate is -2.7°C/km, signifying a stable atmosphere and an inversion layer. Therefore, the mixing height in Miami on the afternoon of December 3 was 1714m. This elevated inversion layer could be due to subsidence inversion which is a common occurrence during winter afternoons like this case. Beyond 2062m, the atmosphere is conditionally unstable with a lapse rate of 6.2°C/km up till 7500m. From 7500m to 16500m, the lapse rate is 6°C/km.

In Los Angeles, the atmosphere is stable from 1970m to 2516m with a lapse rate of -3.3°C/km signifying the presence of an inversion. Therefore, the mixing height in Los Angeles on the afternoon of December 3 was 1970m. This inversion layer also presents conditions corresponding to an afternoon subsidence inversion. From ground level to 1970m however, the temperature decreases at a lapse rate of 6°C/km, implying a conditionally unstable atmosphere. From 5000m to 10000m, temperature decreases at an unconditionally stable lapse rate of 7°C/km. Beyond 10,000m, the lapse rate starts dropping as the tropopause is approached. In the stratosphere beyond 16,200m, temperature starts increasing with height due to the presence of Ozone which is a greenhouse gas.

Figure 7. Variation in temperature, dew point, and pressure with height



4.2. Wind Speed and Direction

There is a general trend of increasing wind speed with height in both the cities which is expected since winds are slowest near the ground due to friction. The winds near the surface in Los Angeles are westerly, while Miami has easterly surface winds. However, at high elevations beyond 8000m, the winds trend westerly due the westerly jet streams. The variation of wind speed and direction with height is plotted in Figure 8 where the direction of arrow is the wind direction and the length of the arrow represents wind speed, i.e., longer the arrow, faster the speed. It can be observed from the figure that winds get faster and the direction changes with height. It can also be concluded that higher winds are faster in LA than in Miami.

4.3. Dew Point and Clouds

The sounding data can be used to infer the height of clouds over the region by comparing the dew point and temperature variation with height. Clouds are present at locations where the temperature is equal to the dew point, meaning that the relative humidity is 100% and it is cold enough for water vapor to condense and form clouds. In the sounding data for Miami, at no height does the temperature drop to as low as the dew point. However, in Los Angeles, this is not the case. LA has clouds from 700 to 1500m and from 5600 to 6000m. Figure 9 depicts the presence of clouds over LA and Miami.

Figure 8. Vertical Variation in Wind Speed and Direction

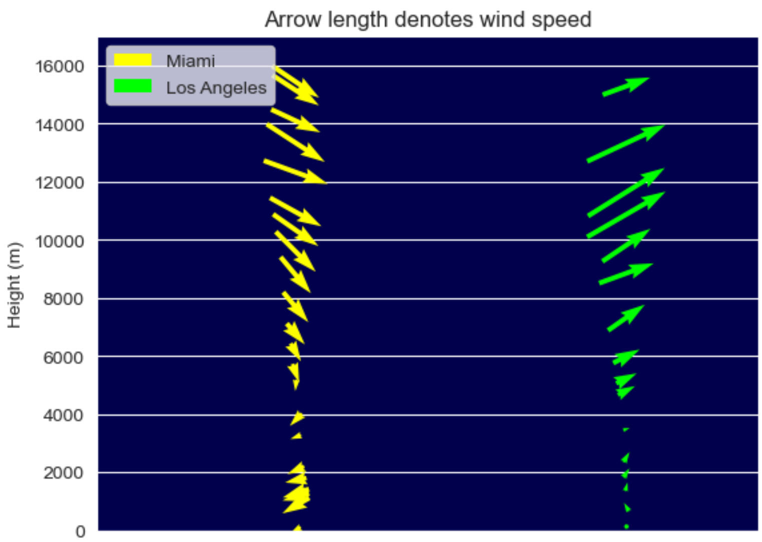
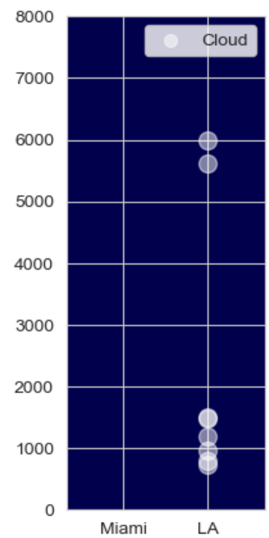


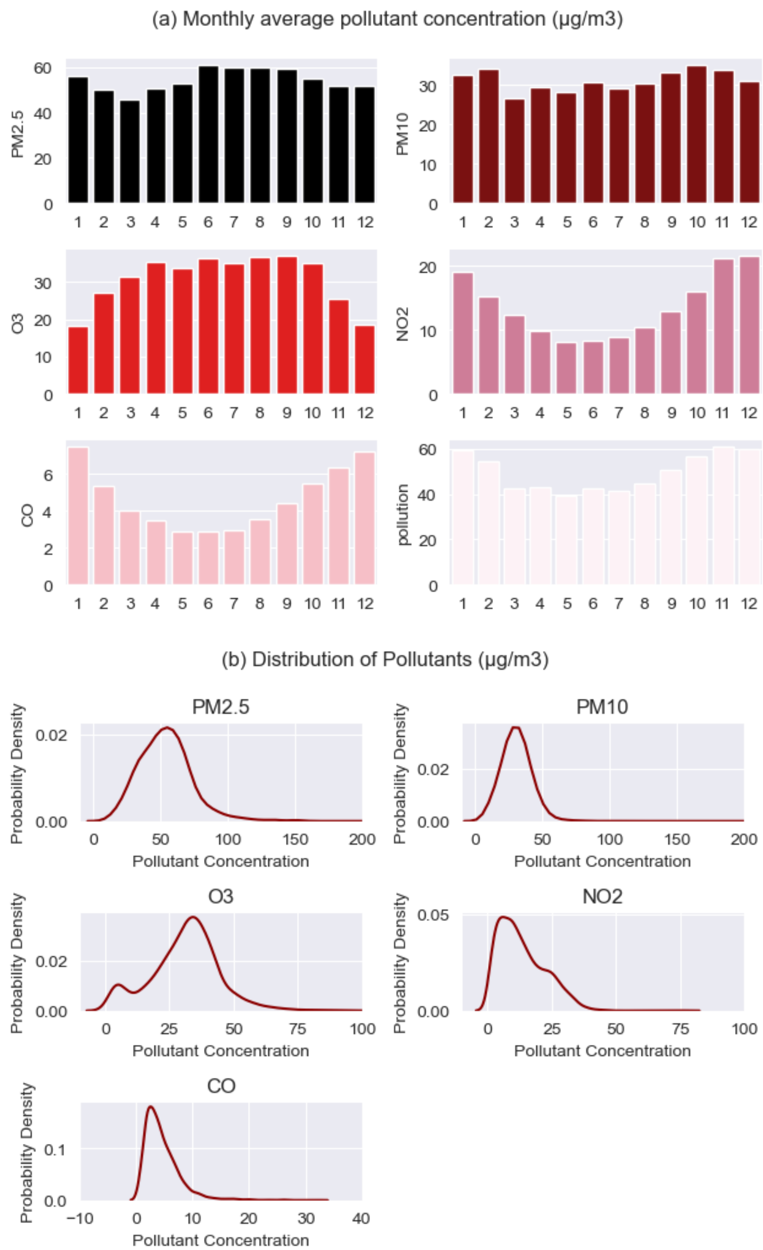
Figure 9. Cloud Height



5. Air Pollution Analysis

While analyzing weather patterns in LA, I was also interested in observing and analyzing some air quality data from Los Angeles. The air quality data covers 2014 to present. Although I failed to find interesting correlations between weather variables and pollutant concentrations, I did find a weak correlation ($R^2 = 0.41$) between daily temperature range and gaseous pollutants which I fail to explain given the data. I think it would me more interesting to analyze air quality data at a finer resolution than 24-hr by studying diurnal variations in pollutant concentrations, given the impact of radiation inversions on lower atmosphere stability and the difference in the extent of anthropogenic activity during day and night. However, despite the lack of insightful findings, in Figure 10, I have presented the average daily pollutant concentrations by month and a distribution of pollutant concentrations for Los Angeles. The pollution plot in the figure is a quantity calculated as the sum of standardized concentration (removed the mean and scaled by the standard deviation) of each pollutant. It is interesting to note that gaseous pollutants have a lower concentration during summer months and peak in December – January. Particulate pollution is the lowest in the month of March.

Figure 10. Air Quality Data Analysis



The data and code for the data analysis presented in this report can be found at this [GitHub repository](). Hope you enjoyed reading this report half as much as I enjoyed preparing it. Thanks Prof. Jacobson and the teaching team for an insightful course, enjoyed every bit of it. Happy Holidays!