Lab Activity No. 2: Observing the vertical temperature pattern of the atmosphere, and its relationship with air pollution on the ground

Crizzia Mielle de Castro

1 General and Specific Objectives

1.1 General Objective

- To observe the effects of changes in lower atmosphere temperature to air pollution

1.2 Specific Objectives

- To determine how temperature changes with height in for a whole week (Sunday to Saturday)
- To observe the daily variations of temperature for different heights (0m, 150m, 300 m, 500 m, 800m, 1000m)
- To relate the changes in vertical temperature to ground measurements of air pollution from previous studies

2 Description of Site/Sampling Area

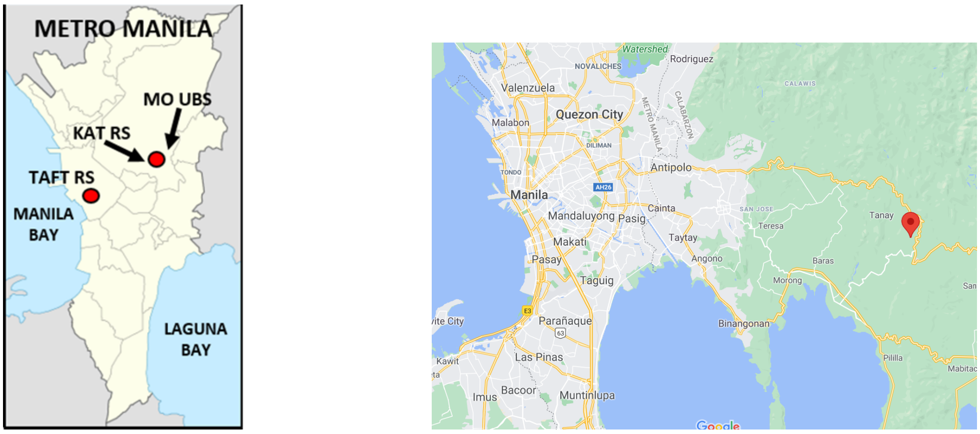
We focus our analysis of vertical temperature measurements on the Tanay, Rizal synoptic weather station ($14.56^o N$,$121.36^o E$; station no. 98433). On the other hand, our air pollution sampling sites are situated in the Manila Observatory (urban background station), Katipunan Ave. (roadside), and Taft Ave. (roadside) [1]. All the pollution sampling sites are located in Quezon City, Metro Manila. The location of our areas of interest are illustrated on the map in Fig. 1.

The Tanay weather station is situated in a rural mountainous area just outside of Metro Manila, about 50km from Katipunan Ave., and the Manila Observatory. The air pollution sampling sites were located in highly urban highways frequented by vehicles such as trucks, private cars, and public transportation.

3 Review of Related Literature

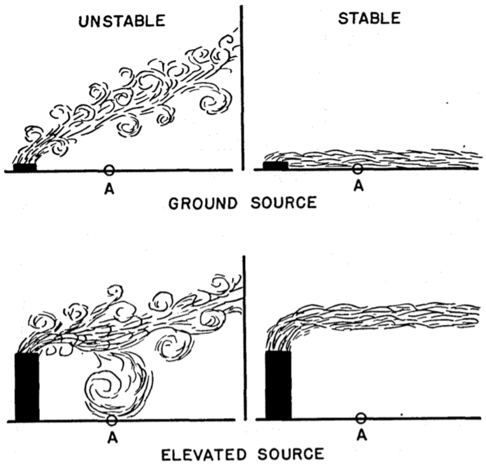
A lightweight box carrying weather instruments and a radio transmitter compose a radiosonde [2]. To take vertical measurements, a weather balloon carries the radiosonde upwards until around 30 km (about where the stratosphere is). We expect temperature to decrease with height in the troposphere until it reaches an inversion layer (the tropopause) and into the stratosphere, where temperature begins to increase with height.

Within the lower atmosphere, we can sometimes experience a temperature inversion—temperature increases (instead of decreasing) with height [2]. On cloudless nights



(a) (b)

Figure 1: Map locations of (a) air pollution sampling site and (b) synoptic weather station indicated by the red marker



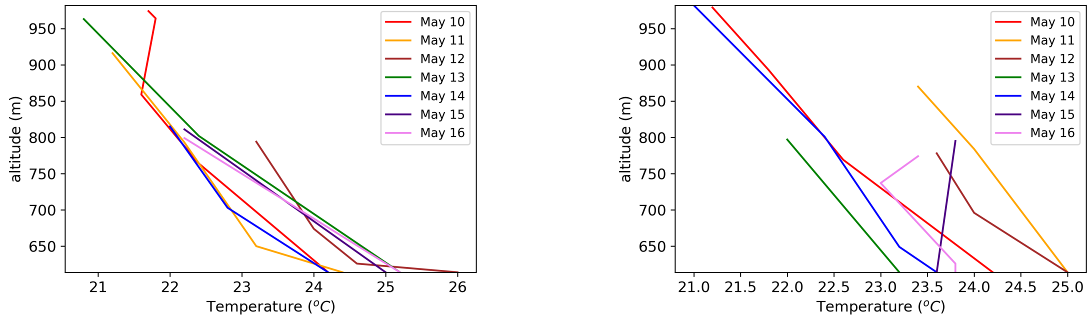
(a)

Figure 2: Smoke plumes from different sources and different atmospheric conditions (from [3])

with weak winds, surface temperatures tend to be colder than the air aloft; the cold surface air gets smooshed by the warm air on top. We consider the atmosphere unstable when temperature decreases with height, and a stable when the opposite occurs.

The effects of atmosphere stability on surface pollution concentrations depend highly on the location of the pollution source: ground or elevated source [3]. We see that pollution tends to accumulate at the surface from a ground source in a stable atmosphere (Fig. 2). However, pollution tends to flow down to the surface from an elevated source in an unstable atmosphere, since air mixes.

Previous studies show that ground pollution concentrations tend to increase during temperature inversions [4–7]. The increase is especially prominent during strong temperature inversions, or when temperatures rapidly increases with height. Temperature inversion effects also become more prominent in measurements done within the planetary boundary layer (about 1km altitude); this is where surface conditions greatly influence the atmosphere. Thus, we focus our analysis on synoptic measurements taken within 1km altitude only.



(a) (b)

Figure 3: Vertical temperature profiles from May 10 to May 16, 2015 in the Tanay weather station for altitudes less than 1000m in the (a) morning, 8:00 PHT and (b) evening, 12:00 PHT

4 Methods Framework

The radiosonde data for the Tanay weather station (station no. 98433) was obtained from the following link: http://weather.uwyo.edu/upperair/sounding.html. The parameters of interest for this paper include the altitude (in meters), and the air temperature (in ^oC). Any measurements beyond an altitude of 1000 m was not included in the analysis.

First, I plot the temperature as a function of height for each day from May 10 to May 16, 2015. For comparison of morning and evening temperatures, I separated the plots for 00Z or 8:00 PHT, and 12Z or 20:00 PHT.

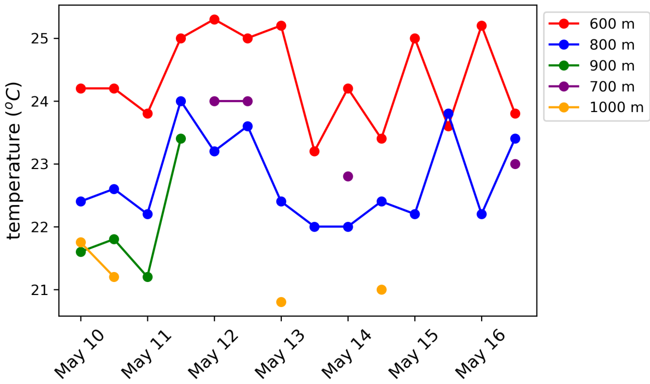
The radiosonde data only had measurements for altitudes greater than 600 m, so I just obtained the temperature time series for the following altitudes: 600 m, 700 m, 800 m, 900 m, and 1000 m. Also, most measurements weren't taken at these exact altitudes, so I rounded off to one significant digit all measured altitudes. Some temperature measurements were also taken more than once for each altitude, so I just took their average. For example, in the morning of May 10, we have two temperature measurements: 23.5^oC at 620 m, and 23^oC at 635 m. Thus, we obtain 23.25^oC at 600 m.

5 Results and Discussion

The daily plots of temperature as a function of height (Fig. 3) tend to follow similar trends—temperature decreases with height. However, certain days such as May 15 and May 16 experienced temperature inversion during the evening. During May 15, the temperature was increasing with altitude, while in May 16, the temperature started increasing at about 725 m. May 10 also experienced a temperature inversion during the morning at about 850 m. We observe that temperature inversions are more common during the evenings, since the Sun begins to heat up the cold surface temperatures during the day.

The temperature time series for different altitudes (Fig. 4) follow the general trend from Fig. 3—temperature decreases with height. Some of the days have missing data, since no temperature measurements were made in those altitudes. We also notice the high diurnal and daily variability of air temperature (about 2^oC).

According to Alas et al., the black carbon concentrations increase in the urban background site (MO UBS in Fig. 1a) during the evening, since vertical convection decreases. The concentrations decrease again during the mornings, since thermal convection increases. In other words, the atmosphere stabilizes during the evenings, then destabilizes during the mornings.



(a)

Figure 4: Temperature time series for altitudes 600 m, 700 m, 800 m, 900 m, and 1000 m during the morning and evening of May 10 to May 16 in the Tanay weather station.

For the closest road site (KAT RS in Fig. 1a), the paper found that strong winds originated from the southwest from afternoon to evening [1]. Apparently, this coincided with high vehicular traffic in the site, so black carbon concentrations increased during the afternoon and evening. Looking at the spatial distributions, we notice higher concentrations of black carbon in areas with high vehicular traffic. Thus, we can consider vehicle exhausts, a mobile ground source, as our primary pollutant source.

Based on temperature profiles in Tanay, we observe more common temperature inversions during the stable evenings, which matches with the paper's observations. Tanay, a mountainous area, is found east of the road site. Possibly, the strong evening temperature inversions, and valley inversions contributed to increased black carbon concentrations.

References

[1] H. D. Alas, T. Müller, W. Birmili, S. Kecorius, M. O. Cambaliza, J. B. B. Simpas, M. Cayetano, K. Weinhold, E. Vallar, M. C. Galvez, et al., Spatial characterization of black carbon mass concentration in the atmosphere of a southeast Asian megacity: An air quality case study for metro Manila, Philippines, *Aerosol and Air Quality Research* **18**, 2301 (2018), ISSN 20711409.

[2] C. D. Ahrens, *Third Edition Essentials of Meteorology* (2000), ISBN 9780123736154.

[3] H. Neuberger, The Vertical Distribution of Atmospheric Properties and Air Pollution, *Air Repair* **3**, 205 (1954).

[4] A. Al-Hemoud, M. Al-Sudairawi, M. Al-Rashidi, W. Behbehani, and A. Al-Khayat, Temperature inversion and mixing height: critical indicators for air pollution in hot arid climate, *Natural Hazards* **97**, 139 (2019), ISSN 1573-0840.

[5] T. T. Trinh, T. T. Trinh, T. T. Le, T. D. H. Nguyen, and B. M. Tu, Temperature inversion and air pollution relationship, and its effects on human health in Hanoi City, Vietnam, *Environmental Geochemistry and Health* **41**, 929 (2019), ISSN 1573-2983.

[6] S. Janhaïl, K. Frans, G. Olofson, P. U. Andersson, J. B. C. Pettersson, and M. Hallquist, Evolution of the urban aerosol during winter temperature inversion episodes, *Atmospheric Environment* **40**, 5355 (2006).

[7] A. Widawski, The influence of atmospheric circulation on the air pollution concentration and temperature inversion in Sosnowiec. Case study, *Environmental Socio-economic Studies* **3**, 30 (2015).