4.2 Measurement of Ozone and Carbon Monoxide at Mountain Sites Such as Mt. Fuji

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1. Good ozone and bad ozone

The word "ozone" calls to mind the ozone layer, which is the "good ozone" that protects us from harmful solar ultraviolet rays. You might have heard about the destruction of ozone layer by chemical reactions with Freon gases, which happens 10-15 km above the Earth's surface in the stratosphere. However, atmospheric ozone near the surface in the troposphere is poisonous to plants, animals, and also humans because it is so chemically reactive. Therefore, increases in "bad" tropospheric ozone must be avoided.

2. Ozone air pollution

In Japan, severe air pollution is regarded as something that was a problem in the 1960s and 1970s, which was the so-called period of high economic growth, and you might remember the phrase "photochemical smog" in relation to that period. Currently, Japan does not suffer from the atmospheric pollution that is still seen in many other big Asian cities and has a greatly improved environment. However, the increase in the amount of oxidants, mostly consisting of ozone, is still a problem in large Japanese cities.

At most of the environmental monitoring sites in Japan, the environmental standard for oxidant concentrations (less than 60 ppb) is not met. Ozone, which we use as a general term for oxidants here, is not directly emitted but is generated by secondary photochemical reactions of atmospheric pollutants. Thus, it is hard to regulate ozone levels at urban area. Also, ozone is transported from neighboring countries and cities, raising the background concentration and making it difficult to regulate the ozone concentration only by domestic countermeasures.

In addition, ozone behaves as a greenhouse gas in the troposphere and in the stratosphere. It is the third most potent greenhouse gas after carbon dioxide and methane. However, ozone is not considered in greenhouse gas reduction measures because it is not directly emitted.

3. Carbon monoxide concentrations at remote sites

Carbon monoxide is mainly generated by incomplete combustion and burning, and can be dangerous to human health. Carbon monoxide concentrations are higher in urban areas because of combustion sources; however, the concentrations are below the environmental standards in most Japanese cities. However, it serves as a useful tool in atmospheric research.

Nitrogen oxides (NOx) are also generated from incomplete combustion at the same time as carbon monoxide, and tropospheric ozone is generated through NOx photochemical reactions. NOx disappear after a few days, whereas ozone remains for several weeks and carbon monoxide remains for 1-2 months. Therefore, simultaneous measuring of the atmospheric concentration of carbon monoxide and ozone provides information about how the atmosphere is affected by air pollution.

4. Advantages of mountain observations

Most pollutant gases are emitted from highly populated cities and industrial areas. To protect the residents of these areas, there are many monitoring stations in urban areas. On the other hand, remote sampling sites, which are far from pollution sources, provide representative data for the atmosphere in a certain region. Measuring the concentrations of pollutants at remote sites gives us useful information about the transport of pollutants from source areas.

These observations are mainly performed on the coast of the Japan Sea and on remote Japanese islands. They provide data on long-range transportation of pollutants from continental Asia. At mountain sites, clean air free from ambient pollution can be observed. In particular, at the top of Mt. Fuji, atmospheric observations provide information about the status just upstream of the heavily populated Kanto region. At the mountain sites, the wind blows from the valley during the day and from the mountain at night. Thus, the air at the summit may be affected by air from the atmospheric boundary layer during the day, even when free tropospheric air is observed at night. The summit of Mt. Fuji is 3776 m above sea level, which is much higher than other mountains in Japan, and the effect of the daytime boundary layer is smaller. This is a particular advantage of Mt. Fuji.

For continuous measurements, the availability of commercial electricity is a vital issue. For example, at Mt. Norikura, no commercial electricity is available and continuous measurements rely on generators. However, these generators are a source of pollutants, so the air inlets are carefully separated from the generators. Nevertheless, it is not easy to get good data because it depends on the wind direction.

Mt. Fuji also has the advantage of a commercial electricity supply, even though stays at the summit are limited to 2 months during the summer. The lack of observations from fall to spring, when strong westerlies predominate, is a problem for measuring long-range transportation of pollutants. However, useful information can still be obtained from the summer observations (Fig. 4.2-1).

5. Results obtained at the summit of Mt. Fuji

The concentration of carbon monoxide and ozone varies, even though at the summit of Mt. Fuji there are no sources nearby and it is in the free troposphere. The variations in the concentrations of carbon monoxide and ozone are similar because polluted air from the source contains high concentrations of carbon monoxide, which can undergo photochemical reactions to produce ozone.

A back trajectory study was performed to see what path the air took to arrive at the summit of Mt. Fuji. Air masses with high carbon monoxide and ozone levels usually originate from continental Asia, whereas air masses with low carbon monoxide and ozone levels originate from over oceans. Measuring these levels can identify the origin of air masses. However, air masses with high ozone and low carbon monoxide levels are observed. Back trajectory studies show that these mysterious clean air masses often come from the upper atmosphere. These air masses showed low humidity; air masses with low humidity often have low carbon monoxide and high ozone levels.

When an air mass ascends, the water vapor in it cools and is removed by condensation; so, at higher altitude, the concentration of water vapor is low. Because sources of carbon monoxide are near the ground, the concentration of carbon monoxide in the upper air mass is also low. The concentration of ozone is high in the upper air mass, owing to the ozone layer above. Air masses with low carbon monoxide and high ozone levels provide an index of upper air migrating to the top of Mt. Fuji.

Mountain observations of carbon monoxide and ozone levels provide unique information beyond that about polluted air masses from urban areas (Fig. 4.2-2).

Fig. 4.2-1: The author and instruments at MFRS laboratory

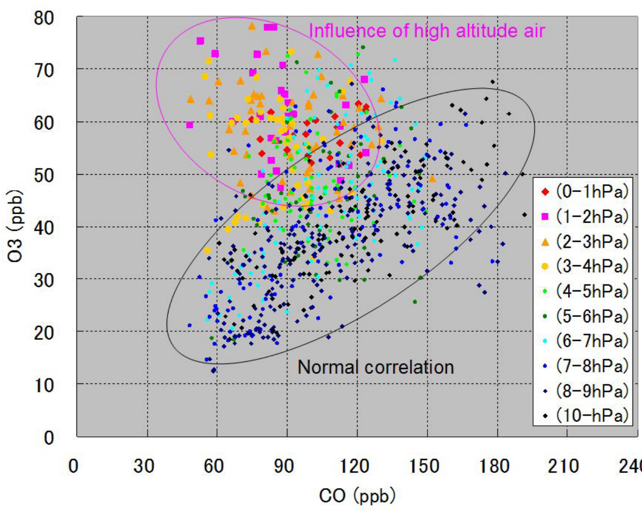

Fig. 4.2-2: Correlation plot of CO and O_3 by different symbols for water content during summer in 2013.
CO and O_3 usually show linear correlation, but low CO and high O_3 appear with low water vapor, indicating the influence of high altitude.