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LASER INVESTIGATION OF SMOKE-DUST ACCUMULATION LAYER

By

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Laser Investigation of Smoke-dust Accumulation Layer

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Abstract

By using ruby laser radar in an industry area where smoke and dust are abundant, the altitude of smoke-dust accumulation layer can be measured when the near-earth atmosphere layer is stable. This has definite and practical value for understanding the situation of distribution and development of air pollution as well as the study of diffusion rules of air pollution.

1. Investigation Condition

Under a certain meteorological condition, the smoke and dust expelled from factories often do perse but accumulate at a near-earth layer of atmosphere to form a smoke-dust accumulation layer instead.

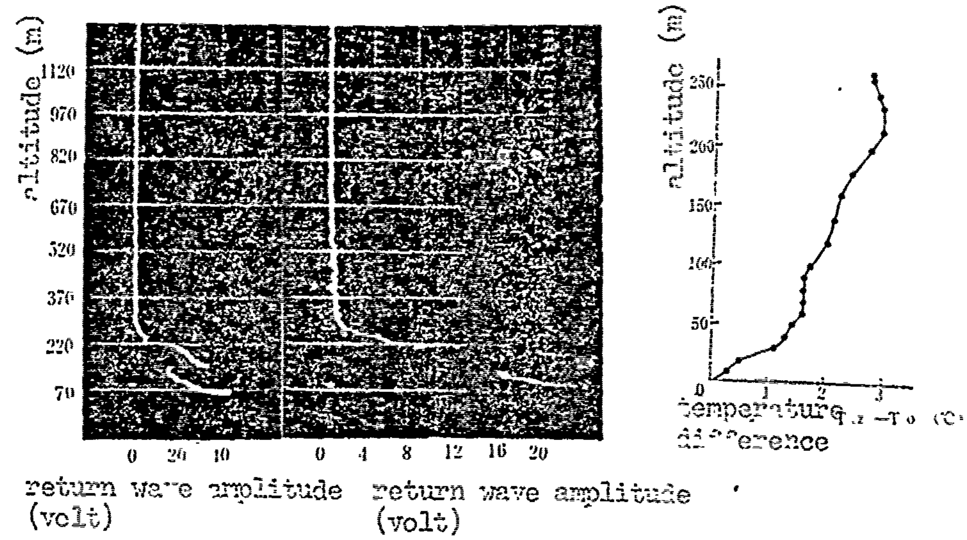
From September through November of 1974, in an industry area in China,[1] we use ruby laser radar to investigate the changes of smoke-dust laser return wave form as altitude changed under various weather conditions and to analysize the relationship between smoke-dust return wave form and the stability of atmosphere and finally we try to explore the possibility of using laser to measure the altitude of smoke-dust accumulation layer.

The laser radar is set on the roof of a building of which the height is 23 metres. In that area there are many factories, which altogether create a forest of chimney from which comes out great volume of smoke. As a consequence, smoke and dust grow abundant in that area. We attain the altitude of smoke-dust accumulation layer by taking the altitude of smoke-dust laser return wave amplitude, which will change drastically as the altitude changes, as criterion. Due to the fact that the investigation blind area of laser radar is 100 metres, only the smoke-dust laser return wave outside the slant distance of 100 metres can be examined. Thus the laser investigation of smoke and dust adjacent to earth is limited.

2. Investigation Results

The condition that causes smoke-dust accumulation at the near-earth layer is not only related to the stability of atmosphere, but also related to the amount of smoke expelled from factories, the altitude the smoke can fly and the diffusing situation of the smoke in atmosphere. So using the form of smoke-dust laser return wave to analysize the altitude of smoke-dust accumulation layer is a rather complicated operation.

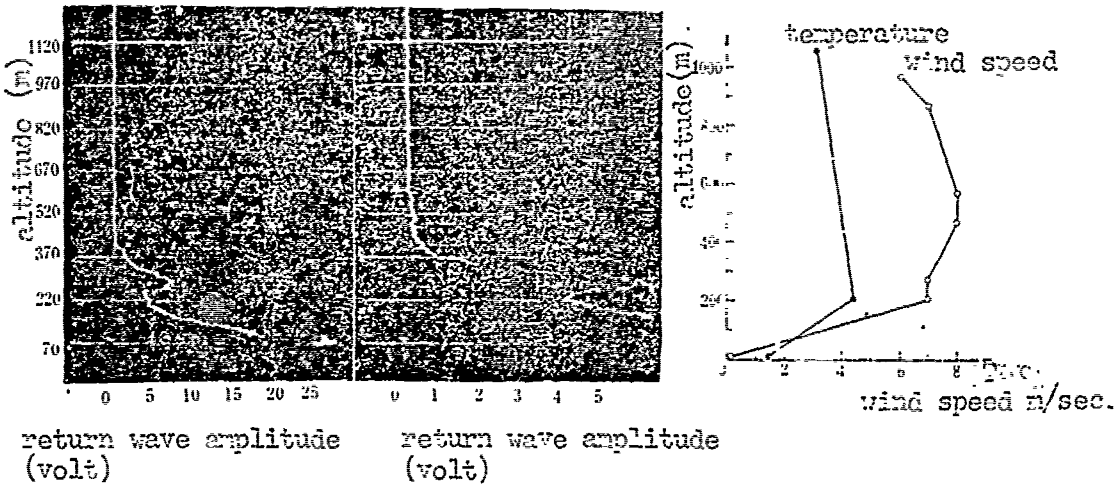
In Figure 1-3, the typical results of our three investigations are shown and they are complemented with contour lines of temperature and wind speed. Generally, according to the fundamental characteristics of laser return wave, the amplitude of laser return wave would rapidly reduce as the altitude changes. Basically it is similar to what Figure 3a shows. At a certain altitude of atmosphere, when great amount of smoke and dust



a. Laser return wave form of smoke and dust
b. The temperature difference measured by captive ballon varies as altitude changes

Figure 1 The result of laser investigation made at 6 o'clock on October 16, 1974

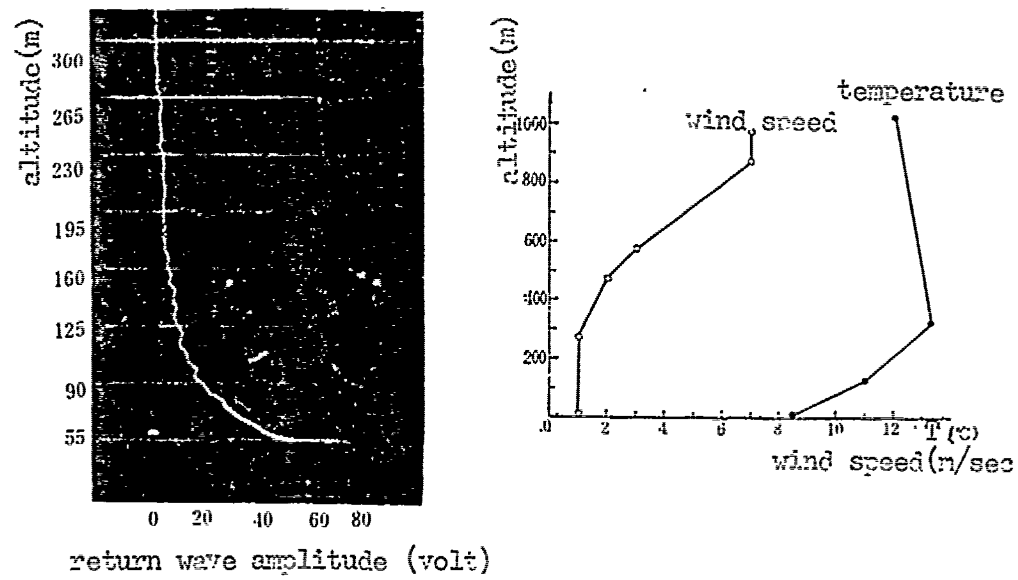
begin to accumulate and form an accumulation layer, the smoke-dust concentration is much greater than that at a lower layer. The laser return wave at this altitude now suddenly becomes strong, and, at the upper boundary of the smoke-dust accumulation layer, the amplitude of return wave often suddenly becomes smaller, as shown in Figure 1a and 2a. The amplitude of return wave in Figure 1a suddenly becomes large at an altitude of about 140 metres and that in Figure 2a begins to become large at an altitude of about 220 metres. This indicates that smoke-dust begin to accumulate at altitude about 140 and 220 metres respectively and form a smoke-dust



a. Laser return wave form of smoke and dust
b. Contour line of actually measured temperature and wind speed

Figure 2 The result of laser investigation made at 7 o'clock on October 15, 1974

accumulation layer with high degree of concentration. Therefore, the altitude of smoke-dust accumulation layer can be probably decided by the form of laser return wave. But the real situation is not so simple. For instance, Figure 3a shows the result of laser investigation made at 7 o'clock on October 26 and Figure 3b gives the contour line of atmosphere temperature and wind speed at that time. These lines indicate that a strong inversion layer with thickness of about 330 metres appears on the near-earth layer, and the temperature gradient reaches 15°C/km and atmosphere Richardson number is $R_i > 10$, so the atmosphere is stable. Smoke and dust pack the layer contiguous to earth and the visibility only reaches one kilometer or so, from there smoke and dust begin to accumulate up to great amount and it is hard for them to diffuse upward. Because of the limit of



a. Laser return wave form of smoke and dust
b. Contour line of actually measured temperature and wind speed

Figure 3 The result of laser investigation made at 7 o'clock on October 26, 1974

laser radar blind area, the laser return wave investigated as shown in Figure 3a rapidly reduces following the change of altitude and there is no such peak value of laser return wave as shown in Figure 1a and 2a.

Even there is laser return wave peak Fig. 1a and 2a value responding to the smoke-dust accumulation layer, the corresponding weather condition is not necessrily the same. The weather condition responding to laser return wave in Figure 1a is that there appears a strong inversion layer at the near-earth layer and the temperature gradient reaches 14°C/km and the altitude of the inversion layer is about 230 metres. It is higher than the altitude (about 140 m) where smoke and dust begin to accumulate up to a great amount but it is closer to the altitude of the upper boundary of the smoke-dust accumulation layer (about 220m). However, in Figure 2a, the weather condtion responding to laser return wave is different. From Figure 2b, it can be seen that the near-earth atmosphere at this time forms an inversion layer of a thickness about 210 metres, the temperature gradient reaches 15°C/km and the atmosphere Richardson number is $R_i \simeq 4$. Besides, from an altitude of 210 metres to 1 kilometer, although temperature following the changes of altitude will become lower gradually, the atmosphere Richardson number is $R_i > 10$, so the atmosphere layer is still stable. This means that the laser return wave cannot completely respond to the structure of this kind of atmosphere temperature distribution.

3. Conclusion

In an industry area where smoke and dust are abundant, when the near-earth layer of atmosphere is stable, the altitude of smoke-dust accumulation layer can be measured by using ruby laser radar. This will have definite and practical value for understanding the situation of distribution and development of air pollution as well as the study of the diffusion rules of air pollution.

But the weather condition responding to laser return wave is complicated. Difficulties are often found remaining when we try to study the structure of atmosphere temperature distribution from the changes of laser return wave amplitude.

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