Studies on net long-wave radiation on clear days in Hefei region

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Abstract

Net long-wave radiation is an important component of radiation budget. The knowledge of induced factors (such as water vapor, aerosol) of radiation budget provides an opportunity for understanding the impact of environmental changes on climate. Utilizing the radiation data observed by pyrgeometer at definite times every day from 2003 to 2007 at SKYNET Hefei site in East China, the characteristic of net long-wave radiation over grassy land is discussed on 293 clear days. Meanwhile, based on these five years observations of integrated water vapor by microwave radiometer WVR-1100, variability of the atmospheric water vapor on sunny days has been statistically analyzed. And the aerosol optical property in the corresponding period is also obtained by an automated two wavelength (1064nm, 532nm) polarization (532nm) lidar. For the value of integrated water vapor, validation is given by a local radiosonde and good agreement is shown. As to the lidar dataset, we apply the Fernald's method to derive the extinction coefficient. The profile of aerosol extinction coefficient is compared with anther lidar system PML and indicates great agreement. Then the AOD under the height of 3 km is calculated by layer-integrated extinction coefficient. This study mainly addresses the daily and seasonal variations of net long-wave radiation, integrated water vapor and AOD as well. We attempt to characterize the optical property of aerosol and the value of integrated water vapor and their effects on the net long-wave radiation over Hefei. The results show that some certain negative correlations are considered to occur between the latter two kinds of factors and the net long-wave radiation. And especially in summer the effects of water vapor and the aerosol on net long-wave radiation are very obvious. Large water vapor and aerosol loading lead to a very low net long-wave radiative effect.

Keywords: net long-wave radiation; integrated water vapor; AOD

1. Introduction

The radiation balance of the Earth system is an accounting of the incoming and outgoing components of radiation. Net long-wave radiation is an important component of radiation budget. And it is a measure of the difference between outgoing long-wave radiation from the earth surface and incident atmospheric long-wave counter-radiation. Many factors determine the value of net long-wave radiation[1)]. In this paper, we analyze the seasonal variation of net long-wave radiation, integrated water vapor and aerosol optical depth as well using the observed data on clear day from 2003 to 2007 at SKYNET Hefei site (31.90N, 117.16E) in East China. Some relationships are found among the three foregoing parameters. Besides, in order to validate these data, good agreements are acquired by blind validations.

2. Instruments and validation

The measurement site is located at Anhui Institute of Optics and Fine Mechanics, 15 km west of Hefei city. The institute is surrounded by farmland, lake and villages. The factory district is centered in the eastern suburbs of the city. Therefore, influence of urban plume and industrial emission on the observed data is less important. Data obtained from two pyrgeometers, a microwave radiometer, and a NIES Lidar is analyzed in this paper. The instruments were placed at a height of 1.5 m over short non-irrigated grass and they are operated continuously.

The pyrgeometers (model PIR), manufactured by the EPPLEY LAB.INC., were calibrated by Precision Infrared Radiometer in Eppley's Blackbody Calibration System. Downward and upward long-wave radiation was measured by them in continuous operation. Thus, they were inspected several times per week and an alternate method of calibration was also been done each year to compare the PIR against another calibrated working standard PIR in a cloudless night sky.

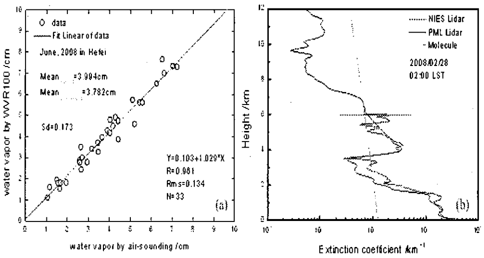

Fig. 1(a) Scatter plot of water vapor retrieved from microwave radiometer data vs. that measured by radiosonde; (b) Comparison extinction profiles at 532nm measured by PML Lidar with NIES Lidar

The Radiometrics WVR-1100 portable water vapor radiometer receives microwave radiation from the sky at 23.8 GHz and 31.4 GHz for total Integrated Water Vapor and Cloud Liquid Water. This instrument does not need to be always calibrated if no change shows in the plot of noise diode injection temperature (i.e. the instrument is sufficiently calibrated.). In this paper, we compared the value of integrated water vapor retrieved from microwave radiometer data and that measured by radiosonde. Figure 1(a) shows the results. It was found from the retrieval results of the microwave radiometer data taken at Hefei in June, 2008 that on average, the retrieved value of water vapor was 0.212 cm greater than that measured by radiosonde and the standard deviation was 0.173 cm; the linear correlation coefficient between the two value is 0.961, and the Rms error was 0.134 cm. In general, good agreement was shown except small difference because of certain non-comparable fact[2].

The NIES Lidar[3] employs 1064-nm fundamental and 532-nm second harmonic of a flash-lamp pumped Nd:YAG laser and the direction of measurement is vertical. The scattered light is received with a 20-cm Schmidt-Cassegrain telescope. The received light is collimated to 1064-nm channel and two 532-nm polarization channel. It is operated automatically, and the 5-minute averaged lidar profiles are recorded every 15 minutes in the continuous observation mode. We apply the Fernald's method iteratively with non-zero boundary value at 6 km to derive the extinction coefficient for the data without clouds. And the aerosol optical depth (i.e. AOD) under the height of 3 km is calculated by layer integrated extinction coefficient. In order to check the reliability of observed data by this Lidar, the profile of aerosol extinction coefficient is compared with anther lidar system PML[4]. The results are shown in the Figure 1(b). The Figure clearly indicates that aerosol extinction profiles for 532 nm measured by the two lidars agree very well. During these 5 years, the number of clear days in every month is shown in Table 1.

Table 1 Number of clear days in every month in Hefei region during 2003-2007

Season	Winter			Spring			Summer			Autumn			
Month	12	1	2	3	4	5	6	7	8	9	10	11	
Number	36	29	26	30	30	24	14	7	13	20	30	34	293

3. Results and discussion

3.1. Typical daily variation

Net long-wave radiation was determined from measured upward and downward long-wave radiation by the flux difference between them. This section gave a typical example of the daily variation of long-wave radiation, aerosol optical depth and integrated water vapor. Meanwhile the relationships between net long-wave radiation and anther two parameters were shown.

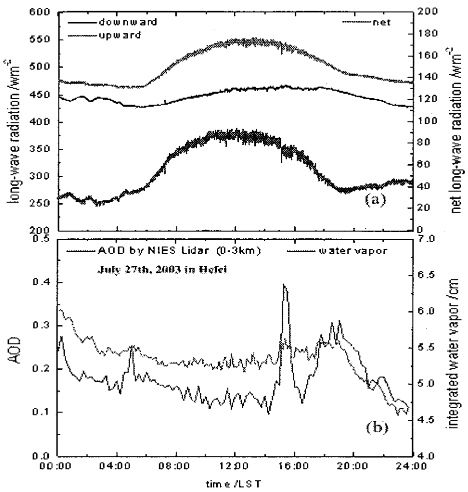

Fig. 2 the diurnal variation of long-wave radiation, AOD and water vapor observed in Hefei on July 27th, 2003

Figure 2 shows that the 24 hours variations of long-wave radiation, AOD and water vapor were observed in Hefei on July 27th, 2003. It was a sunny day except for the occurrence of low cloud at a height of 2-3km occasionally. From figure 2 (a), we can see the downward, upward and net long-wave radiation experience an obvious variation with big value in the daytime and small at night. Figure 2 (b) gives us that the diurnal variation of AOD and integrated water vapor has similar trend. We can also find the value of AOD rises quickly due to clouds (e.g. at about 15:00 pm). Furthermore, the results on figure 2 show that some certain negative correlations are considered to occur among these three parameters (i.e. the relative variation of net long-wave radiation is effected by whether aerosol and water vapor rise or fall at a certain degree). Because the mass of water vapor and aerosol in the air increase, the downward long-wave radiation will enhance. Accordingly, the net long-wave radiation will decrease to some extent.

Besides, many other factors, such as the existence of cloud and the temperature of air or surface, can cause changing of the net long-wave radiation. We do not discuss them in this essay.

3.2. Statistical seasonal variation

In order to investigate the net long-wave radiation under the influence of aerosol and water vapor furthermore, the seasonal variation of long-wave radiation, integrated water vapor and AOD were presented and discussed in detail. The results obtained in figure 3: the value of long-wave radiation and integrated water vapor is monthly mean daily one and the value of AOD (0.03-3.0 km) is derived from lidar by averaging every one in correspondence month. According to the measurements, the downward and upward long-wave radiation have same trend in every month during these 5-year. The lowest monthly mean daily value of them is in January and the maximum long-wave radiation flux occurred in the summer season (see figure 3(a)). But the seasonal variation of net long-wave radiation is widely different marked by summer the lowest and spring the highest value, and the discrepancy between winter and fall is feeble (see the red line in figure 3(b)). And a maximum monthly mean daily net long-wave radiation equals to 96.85 Wm^{-2} on May and a minimum one occurs to 53.04 Wm^{-2} on August.

Interestingly, the seasonal variation of water vapor has the similar tendency with down/upward long-wave radiation, and the minimum monthly mean daily value of integrated water vapor is only 0.29 cm in winter and the maximum is 5.20 cm in July to August with a big leap (see the blue line in figure 3(b)). From figure 3(c), the lidar derived monthly average AOD (0.03-3.0 km) shows no great fluctuant. But it still appears much larger average value in spring and summer and a relative small one in July. That's because the dust weather sometimes happen in spring and increase the value of AOD. And the summer rainfall in July makes the air in Hefei cleanly and decreases the value of AOD.

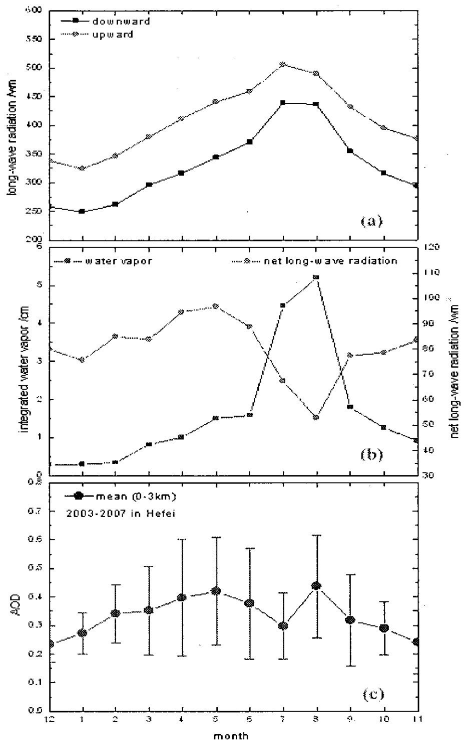

Fig. 3(a) the monthly mean daily value of long-wave radiation; 3(b) the monthly mean daily value of net long-wave radiation (red line) and integrated water vapor (blue line); 3(c) the lidar derived monthly average AOD (0.03-3.0 km) over Hefei from 2003 to 2007 on clear days

Well, in figure 3 we can conclude that in summer the effects of water vapor and the aerosol on net long-wave radiation are obvious. To some extent, negative correlations are considered to come up like the daily variation. Large water vapor and aerosol loading lead to a very low net long-wave radiative effect. However, in other seasons these relationships are not very evident. In my opinion, many other factors, such as the existence of cloud and the temperature of air or surface, maybe play an important role in the net long-wave radiation and we will discuss them in the near future work.

4. Summary

Net long-wave radiation is of major importance for all radiative balance studies. Under different weather/climate, many factors affected on net long-wave radiation must be discussed. We have primarily analyzed the changing of water vapor and aerosol could lead to variation of net long-wave radiation over Hefei in clear days. In some cases, the two parameters are playing a great role in net long-wave radiation (e.g. in summer) and maybe the other factors should be required for more detailed analyses.

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