RADIATION OF ALL WAVELENGTHS ON FINE WINTER DAYS INSIDE AND OUTSIDE LOW-LATITUDE CITIES OVER PLATEAU[1]

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ABSTRACT

The observation of radiation of different wavelengths was conducted in the urban and rural areas of Kunming City. The main results for clear days obtained in this paper are summarized as follows. (1) In the urban area, the fluctuation of radiation of different wave length are larger in the urban area due to strong effect of pollution. The radiation (difference and ratio between urban and rural areas) is lesser in the urban than in the rural areas. The difference is outstanding in the morning when the pollution is strong. (2) In the urban area of cities on low-latitude plateau, percentage of radiation of different wavelengths in total radiation differ between the morning and afternoon on fine winter days, so do that between the urban and rural areas and relevant variations, and the difference is most substantial at the time before midday when the air pollution is serious. (3) The difference between the urban and rural areas also exists for the diurnal total, totals for the time before and after midday in radiation of all wavelengths under the same sky conditions.

Key words: cities, atmosphere, pollution, radiation, wavelength

I. INTRODUCTION

With the increase of pollution sources due to the change in the condition of urban ground surface, the growth of buildings in number and height and concentration of population in cities, the atmospheric conditions have been worsen in the urban areas. Consequently, the radiation conditions have been altered so that the local urban climate as well as the life and health of the inhabitants are affected. As shown in a relevant study at home and abroad (Zhou and Su, 1994), the radiation total can be 10% – 30% less in the urban than in the suburban area, and the decrease can be above 30% if the air pollution is serious enough (Oke, 1978). Little work has been documented in the research on radiation of different wavelengths at home while that overseas (Maurain and Parisien, 1947; Stair, 1967) have indicated that it is easier for shorter-wavelength in the sunrays to be scattered or absorbed and the ultra ultraviolet -radiation in the urban area is only about 77% of the outskirts. When there is dense smog over the Rocky Mountains in California, USA, the ultraviolet radiation can be reduced by more than 90%.

Take the case of Kunming as example. It is a city lying on a plateau in low latitude. Obser-

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vations measured atop buildings in and out of the city are used to study radiation at all wavelengths and their variations, the causes for the difference and respective formation. The work offers foundation for discussion of effects of urban development in low latitude and on plateaus on radiation with all wavelengths, and for intensive research of urban climate and planning of urban architecture. It is also helpful for other study.

II. BRIEF ACCOUNT OF THE RESEARCH

1. *Summary of area of interest*

The urban districts of the Kunming City have grown from 7.8 km^2 (K.P. D.M., 1982) in 1950 to 116 km^2 in 1994 (Y.S.B., 1995). The buildings are becoming larger and higher. At the same time, the daily level of SO_2 has increased to 0.072 mg/m^3 per year and that of the total suspended particles (TSP) to 0.337 mg/m^3 (C.E.Y.E., 1995), both exceeding the standard of Level II for atmospheric quality in China. According to observations in 1982 (Huang, Wang and Chen, et al., 1988), the atmospheric pollutants (SO_2, NO_X) are 3 – 5 times more in the urban than in the suburban area in the dry season (Fig.1a); the pollution is much higher just before midday when the wind is relatively weak that affect the pollutants in the urban air (Fig.1b); the amount rises at 0700 when the wind weakens to the minimum but drops after midday when the wind increases.

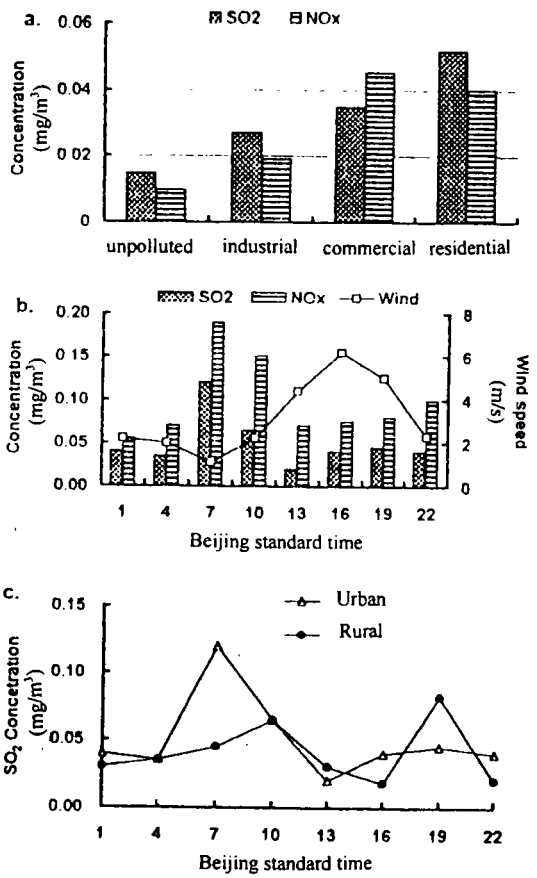

Fig.1.Distribution of pollutants in and out of town, Kunming, on 1 – 6 February, 1982. a. concentration of pollutants in different areas; b. pollutant concentration in town and wind speed out of town; c. temporal variation of SO_2 in and out of town.

2. *Brief account of observation*

On top of the office buildings of the former Kunming Institute of Ecology, the Chinese Academy of Science, in the downtown area of Kunming (5/F, 1909 m ASL) and of the meteorological station on the Taihua Mountain outside the city (3/F, 2368 m ASL), two sites of observation were set up. The roof was all covered with bitumen with no substantial shading. The site in the outskirts is particularly favorable for observation because of its location in the natural forests park southwest of the city (in the upstream of the prevailing wind), thus having good indication of the suburban. The observing instrument was a home-made TBQ-4-1 spectroradiometer and the data was kept with a Britain-made 9 mV automatic recorder.

2. *Weather condition during the observation*

The observation was carried out from January 27 to February 8, 1987, in which February 7 and 8 were two fine days. The work used the local time, which is 1 h 12 s later than the Beijing Standard Time. As the data for February 8 was not complete, that for February 7 was used in the study. Comparisons of radiation with different wavelengths are given in Table 1. It is seen that the radiation total and percentage in and out of the city are close to each other on the two days, with the relative difference smaller than 5%. It is thought that the data for February 7 is also representative of the situation.

Table 1. Comparisons of radiation measures with different wavelengths on February 7 and 8, 1987.

		In town (diurnal)				Out of town (before midday)			
Date	Element	Radiation total	Infrared	Ultraviolet	Visible	Radiation total	Infrared	Ultraviolet	Visible
7 Feb.	Total (MJ/m^2)	19.22	11.27	1.51	6.46	10.36	5.86	0.78	3.72
	Percent (%)		58.6	7.9	33.6		56.5	7.5	35.9
7 Feb.	Total (MJ/m^2)	19.76	11.43	1.54	6.78	10.51	5.96	0.81	3.74
	Percent (%)		57.9	7.8	34.3		56.7	7.7	35.6
R.err. (%)	Total	−2.8	−1.4	−2.0	−4.9	−1.4	−1.7	−3.8	−0.5
	Percent		−1.2	1.3	−2.1		−0.4	−2.7	0.8

III. ANALYSIS AND DISCUSSIONS

1. *Temporal variation of radiation with different wavelengths*

It is seen in Fig.2 that the temporal variation of radiation with different wavelengths is gen-

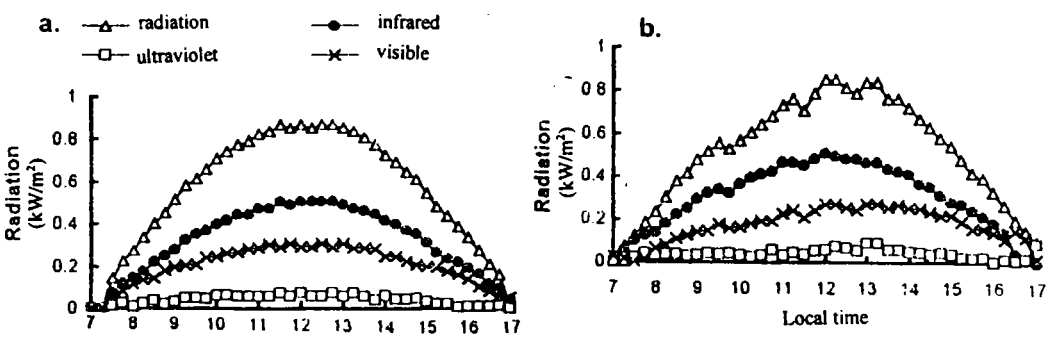

Fig.2. Temporal variation of radiation with different wavelengths in Kunming. a. in town; b. out of town.

erally the same in and out of the Kunming City. For the discrete of the variation of individual radiation, it is larger in town (Fig.2b) than out of the town (Fig.2a), suggesting a greater wave in town where it is subject to urban atmospheric conditions.

2. *Temporal variation of radiation with different wavelengths by percentage*

Fig.3 gives the temporal variation of the percentage for wavelengths in total radiation. It is clear that the infrared radiation takes up the most in and out of town (more than 50%), followed by the visible between 25% and 43 % and the ultraviolet below 10 % in most cases.

Individual radiation varies in the percentage in the total radiation. The infrared in town (Fig.3a) goes in opposite tendency with the visible (Fig.3b), amounting to 60% of the total before midday but decreasing gradually afterwards to 52.3% at 1500; the visible increases the percentage with time, growing from 27.5% at 0800 to 43.3% at 1600. The variation is relatively small out of town in the percentage of the two.

For the temporal variation of the ultraviolet radiation (Fig.3c), the percentage in the total decreases with sunrise and meets a low around 1000 (4.1%) before rising again to have the maximum (10.9%). It drops once again afterwards, being the diurnal minimum (0.5%) at 1600. The ultraviolet out of town varies between 7% and 9% except in some time in the morning and night.

The difference of percentage between the urban and suburban (Fig.4) is larger before midday than after it. The infrared radiation is larger in the total in town than out of town, differing by up to 9.5% but with the value reversing to negative. The difference for the visible is negative comparing urban and suburban before midday, being the maximum at 0800. It decreases with time and stands above zero after midday. For the same comparison, the difference of the ultraviolet varies in a much-complicated way: it is above zero before 0900 and turns to negative ever since; it then, in most cases, rises to positive between 1200 and 1400 before reducing to the zero zone. The difference varies within a range of 5% for the urban and suburban areas.

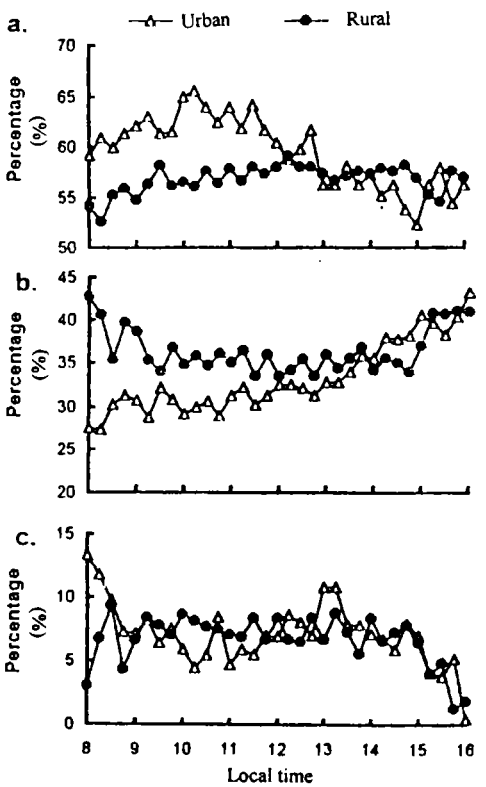

Fig.3. The temporal variation of the percentage for radiation of different wavelengths on February 7, 1987.
a. Infrared; b. the visible; c. the ultraviolet.

It is drawn from the results above that for a plateau city, the overall radiation varies much in both the magnitude and behavioral pattern concerning different wavelengths, forming the difference between the urban and suburban areas and between different time of the day. It is inevitable that the local climate and the associated urban ecological features.

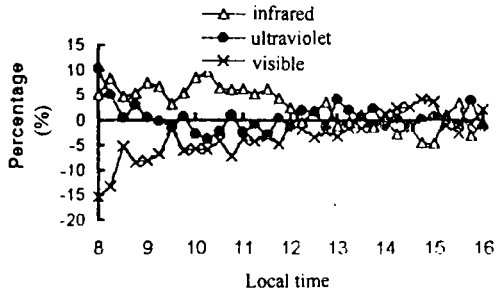

Fig.4. Difference of the percentage for radiation of different wavelengths between the urban and suburban areas on February 7, 1987.

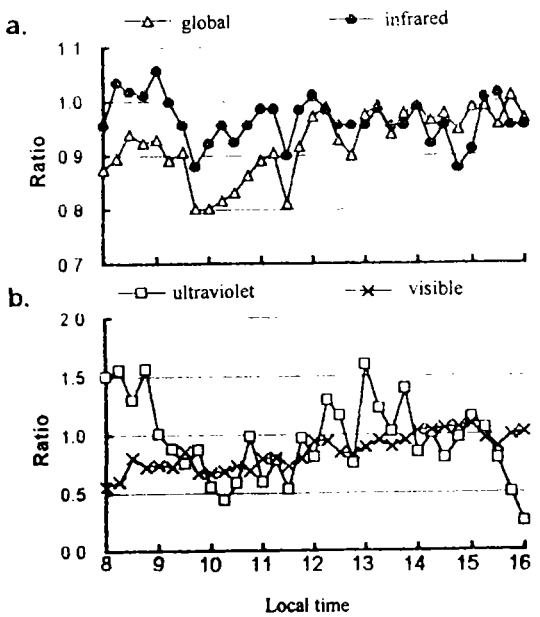

Fig.5. The temporal variation of the ratio of radiation with different wavelengths for urban and suburban areas on February 7, 1987.

3. *Comparisons of radiation with different wavelengths by urban ad suburban area*

Fig.5 gives the ratio of radiation with different wavelengths between the urban and suburban areas. It is known that the ratio is mostly larger than 1 (it is higher in the urban than in the suburban areas) for the total radiation and visible light (Fig.5a). It is smaller before midday with the total being 0.82 – 0.95, and the visible 0.62 – 0.92, decreasing to the minimum around 1000. It then increases after midday to come close to 1. For the infrared and ultraviolet radiation (Fig.5b), on the other hand, the ratio is greater than 1 due to the effects of fogs at the mountainous station and the pattern usually remains unchanged between 0900 and 1200, with the former between 0.90 and 0.95 and the latter between 0.44 and 0.65. After midday, the ratio for the infrared rises to the vicinity of 1 while that for the ultraviolet grows to be larger than 1 from 1200 to 1400, with the maximum being 1.6. It drops below 1 after 1400.

The cause may be that the urban area is subject to air pollution to decrease almost all radiation to a level lower than the suburban area, being consistently so from 0900 to 1200 in conformity to heaviest times of the pollution (Fig.1b, at 1300 BST). For the amount of reduction, the ultraviolet leads by about 50%, similar to studies abroad, followed by the visible (about 30%) and the infrared (8%). The combined effect is such that the total radiation decreases by 10% – 20%. After midday, the difference between the urban and suburban areas for all radiation is getting smaller to approximate to 1, or, the radiation is 60% in town. The ultraviolet radiation becomes higher in town than out of town (Fig.5b) with the ratio being 1.6 when the solar azimuthal angle is getting higher and the atmospheric pollution is reducing to the minimum. Afterwards, with the increase of the solar azimuthal angle and atmospheric pollutants, the radiation is once again made smaller than 1. The lighter pollution in town may be accountable by the fact that the higher wind speed in the dry season of Kunming is favorable for the dissipation of pollutants over the city and weakens the scatter of the short-wavelength radiation, especially when the wind increases after midday to cause the appearance of the minimum of pollutants (Fig.1c). Such large difference at 1300 BST is also resulted from higher radiation over a

low-latitude plateau city and less atmospheric vapor in town due to the lack of supply. In other words, the ultraviolet radiation gets the largest when there are more vapor particles and greater scatter of short-wavelength radiation in the urban area at 1300 BST.

4. *Total radiation with different wavelengths in the urban ad suburban areas*

According to the standard recommended by the World Meteorological Organization (WMO) in 1981 (Pan, 1989), the ultraviolet take up 7.19%, the visible 46.41%, and the infrared 46.40%, of the total radiation, on the upper boundary of the atmosphere.

For the urban area of a low-latitude city on the plateau, Table 2 gives the diurnal total of the radiation with different wavelengths in and out of town on fine winter days, the percentages of individual radiation in the total and difference between the urban and suburban areas and related ratios. It is obvious that except for the ultraviolet, the absolute quantities and ratios of radiation with other wavelengths are smaller in the urban—the total radiation and infrared are 7% and 4% less, respectively and the visible 14% less, while the ultraviolet is, in contrast, 6% more, comparing with the suburban area. For the percentage, the infrared has the larger share both urban (58.6%) and suburban (57.0%) areas, followed by the ultraviolet (7.9% and 7.3%). It is similar to the observation for Paris (K.P.M., 1982), which is higher than that for the upper boundary of the atmosphere. The infrared radiation is higher than Paris in both urban and suburban areas and the ultraviolet radiation is higher in town but close out of town. The visible is 33.6% in town and 36.2% out of town, which are lower than the observation for Paris (43.5% and 40.0%, respectively) and much lower than the value for the upper atmosphere. For the difference in percentage, the infrared is similar to that for Paris, but it is larger in town by1.6% and the ultraviolet is also 1.0% higher in town while the visible is 2.6% smaller in town, just being opposite to the result of Paris. It is suggested that a low-latitude city on plateau is different from a middle-latitude city with a lower ASL concerning radiation of all wavelengths and the difference among them.

Table 2. The diurnal total, percentage in the total, difference and ratio between the urban and suburban areas for radiation of all wavelengths.

Elements	Total radiation	Infrared	Ultraviolet	Visible
Total (MJ / m^2) Urban area	19.22	11.27	1.51	6.46
Percentage (%)	100.0	58.6	7.9	33.6
Total (MJ/ m^2) Suburban area	20.65	11.77	1.43	7.48
Percentage (%)	100.0	57.0	6.9	36.2
Total (MJ/ m^2) Urban – Suburban	–1.43	–0.50	0.08	1.02
Percentage (%)	0.0	1.6	1.0	–2.6
Diurnal total Urban / suburban	0.93	0.96	1.06	0.86

More discussions are made of the diurnal total of individual wavelengths, their percentages in the total radiation, their difference and ratio , between the urban and suburban areas during the time before midday (0700 – 1200 LT) and after midday (1215 – 1700 LT) [See Table 3]. It is seen that the difference is negative and the ratio is smaller than 1 before midday, i.e. the radiation in the urban area is smaller, with largest relative reduction of radiation in the visible (26%) and

smallest relative reduction in the infrared (2%). After midday, radiation follows the same pattern except for the ultraviolet, with the largest relative increment of radiation in the ultraviolet (29%), followed by other radiation between 1% and 6%.

Table 3. The diurnal total, percentage in the total, difference and ratio between the urban and suburban areas for radiation of all wavelengths before and after midday.

Elements	Period of time	Total radiation	Infrared	Ultraviolet	Visible
Total (MJ / m2)	Before midday	9.17	5.76	0.67	2.76
Urban area	After midday	10.05	5.51	0.84	3.70
Percentage (%)	Before midday	100.0	62.8	7.3	30.1
	After midday	100.0	54.8	8.4	36.8
Total (MJ / m2)	Before midday	10.36	5.86	0.78	3.72
Suburban area	After midday	10.30	5.92	0.65	3.75
Percentage (%)	Before midday	100.0	55.6	7.5	35.9
	After midday	100.0	57.5	6.3	36.4
Total (MJ / m2) Urban – Suburban	Before midday	–1.19	–0.10	–0.11	–0.96
	After midday	–0.25	–0.41	0.19	–0.05
Percentage (%)	Before midday	0.0	6.3	–0.2	–5.8
	After midday	0.0	–2.7	2.1	0.4
Diurnal total Urban / suburban	Before midday	0.89	0.98	0.86	0.74
	After midday	0.98	0.94	1.29	0.99

Regarding the percentage of individual radiation in the total radiation, it is found that there is no difference between the percentage for the urban and suburban areas before and after midday, with the infrared taking up the most part (above 54%) and the ultraviolet the least part (between 6.3% and 8.4%). The difference between the urban and the suburb is evident—the infrared is as high as 62.8%, 6.3% more than the suburb. It is indicative of the heat-island effects. There is not much difference in the ultraviolet across the time of midday (–0.2%) and it is only 5.8% for the visible. The situation after midday is just the opposite. The infrared is smaller in the urban area (–2.7%) while the ultraviolet is larger (2.1%). The difference is small for the visible, only 0.4%.

The distribution of the difference across midday for all wavelengths is shown in Fig.7. They

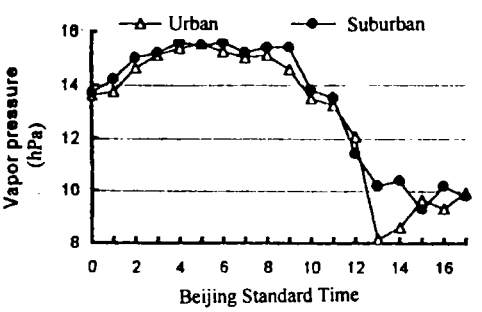

Fig.6. Temporal variation of water vapor in and out of town on May 4, 1996.

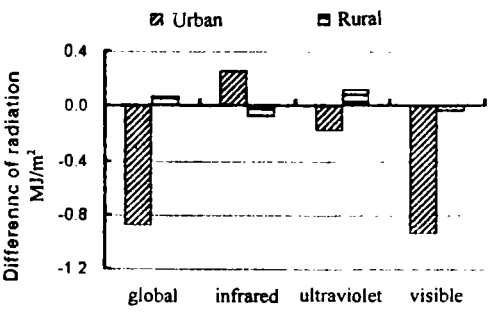

Fig.7. Difference of the percentage for radiation of different wavelengths across midday on May 4, 1996.

are different between the urban and suburban areas—the urban infrared is larger before midday while the ultraviolet and visible are smaller in the same period, with the visible having the largest

difference (0.94 MJ / m^2), constituting a combined effect of higher total radiation before midday in association with little difference in the suburb for all wavelengths across midday. The feature is reflecting the influence of cities and their environmental conditions on radiation in different periods of time and the complexity of distribution of radiation with different wavelengths between the urban and suburban areas of a low-latitude city on the plateau.

IV. CONCLUDING REMARKS

a. Subject to the quality of the atmospheric environment in the urban area, the dissipation of the radiation variation with different wavelengths is larger than that in the suburban area. For all wavelengths of radiation, the absolute and relative quantities (the ratio for urban and suburban) is mostly smaller in town, especially so before midday when the atmospheric pollution is the most serious. The ultraviolet radiation varies in the most unique way: it is smaller in town from 1000 to 1200 and after 1400, when the air pollution is relatively strong, resulting in a difference of only 44% before midday and 24% after midday, of the suburban area; it is, however, larger in town before 0900 when it is foggy and from 1200 to 1400 when there is strong winds and less pollution in the atmosphere and it is 60% more than the suburban area for the largest difference. It is indicated that for a plateau city at low latitude, there are varied behavioral patterns concerning different wavelengths, forming the difference between the urban and suburban areas and between different time of the day. It is inevitable that the local climate and the associated urban ecological features.

b. For the urban area of a low-latitude city on the plateau, there is difference in the radiation with different wavelengths taking up the total radiation in and out of town on fine winter days; the percentages of individual radiation in the total and difference between the urban and suburban areas are also varied concerning the magnitude of values and variation patterns. It results in a large difference between the urban and the suburban, especially before midday when the air pollution is heavy. It shows the effects of wavelength on radiation for a low-latitude plateau city.

c. Significant difference also exists in the diurnal total and the totals for the time before and after midday regarding the radiation with different wavelengths on fine winter days, which is different from results by researchers abroad. It shows the effects of urban environmental conditions on radiation for a low-latitude plateau city.

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