富士山研究第5巻（2011）
1～6頁

富士吉田森林気象試験地における気候特性

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Climatic characteristics of the Fujiyoshida forest meteorology research site

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Abstract

Observations were made from a tall tower for the nine years from 2000 to 2008 to analyze the climatic characteristics of the Fujiyoshida forest meteorology research site. Annual mean global solar radiation, air temperature, vapor pressure and wind velocity were 14.1 MJm^{-2} d^{-1}, 9.5℃, 1.07 kPa and 2.1 ms^{-1}, respectively. Annual precipitation was 1955 mm. The prevailing wind direction was south-southwest. The shape of the hythergraph for the site was similar to that for the Yamanaka AMeDAS station. Global solar radiation in summer was lower than that recorded at nearby weather stations, which is considered to be explained by the presence of fog and cloud because of the high elevation. It is suggested that the Fujiyoshida site has sufficient radiation and precipitation for vegetation growth according to climate classification and a climatic net primary production estimation model.

Key words: Air temperature, Precipitation, Solar radiation, Wind direction

要　旨

富士吉田森林気象試験地の気候特性を明らかにするため、2000年から2008年までの9年間、気象タワーで観測されたデータを使用して解析を行った。年平均全天日射量、気温、水蒸気圧および風速はそれぞれ、14.1 MJm^{-2} d^{-1}、9.5℃、1.07 kPaおよび2.1 ms^{-1}であった。平均年間降水量は1955 mmであった。主風向は南南西であった。ハイサーグラフは山中のアメダスデータと似通っていた。夏の全天日射量は近隣の気象測候所よりも小さく、標高が高いために雲や霧がかかりやすいことが原因と示唆された。気候区分やNPP推定モデルから、この試験地は植物の成長には十分な放射量および降水量があることが示された。

キーワード：気温、降水量、日射量、風向

Introduction

Much of the lower slopes of Mount Fuji in Japan are covered in forest. Japanese red pine (*Pinus densiflora*) mainly grows on the Ken-marubi lava plateau on the northern slope of Mount Fuji. The forest has been studied (e.g., Ohtuska et al. 2003, Tanabe et al. 2004, Han et al. 2004) since the latter half of the 1990 s. Furthermore, a flux observation site was established in 1999 to clarify carbon cycle and energy exchange processes in the forest ecosystem, and fluxes including CO_2 and heat fluxes and meteorological elements have since been measured (Ohtani et al. 2005).

Fujiyoshida forest meteorology research site (AsiaFlux code: FJY) within the enclosure of the Yamanashi Institute of Environmental Sciences is registered on AsiaFlux and Phenological Eyes Network (PEN), and will

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be registered on Japan Long Term Ecological Research Network (JaLTER) soon. Climatic characteristics are basic and important elements for field observation study including biodiversity and carbon dynamics studies. In this study, the climatic characteristics of the Fujiyoshida site are described for future studies including ecological and meteorological application.

Methods

Metrological Observations

A meteorological observation tower is located at 35°27′17″N, 138°45′44″E and an altitude of 1030 m. The height of the tower is 32 m. Pyranometers (CM 6 F and CM 6 B, Kipp & Zonen, Netherlands) and pyrgeometers (PIR, Eppley, USA) were set in upward and downward orientations at the top of the tower. A humidity and temperature sensor (HMP- 45 D, Vaisala, Finland) covered with a radiation shield and equipped with a fan was set at a height of 23 m, 3 m above the canopy. A wetting sensor (PPS- 02 , Prede, Japan) was set at the same height in the summer of 2005 . A vane (A- 802 , Yokogawa Denshikiki, Japan) and anemometer (WM- 30 P, Ikeda Keiki, Japan) were set at the top of the tower. Data were recorded using a data logger (Cadac 2 , ETO Denki, Japan), which was controlled by a personal computer. The sampling frequency was set to once every 15 s, and the averaged data were stored every 5 minutes on a hard disk. A tipping bucket rain gauge (B 071 - 00 , Yokogawa Denshikiki, Japan) was set in an open space approximately 300 m from the tower. Data were recorded using a data logger (KADEC-U, KADEC, Japan [from the beginning of the observation in summer 1999 until July 8 , 2008] or Pulse logger 3639 , Hioki, Japan). Another pyranometer (PCM- 03 , Kipp & Zonen, Netherland) with a fan set at the top of the tower and another humidity and temperature sensor (HMP- 45 D, Vaisala, Finland) covered with a radiation shield and equipped with a fan set at 23 m were used as a backup system to supplement missing data in the main system. Data were recorded using a data logger (Thermodac-E, ETO Denki, Japan) controlled with a microcomputer. The sampling frequency was set to once every minute and data were recorded every 5 minutes. This system worked with a battery to record the signals when the main system didn't work because of electric power failure.

Data processing

Net radiation was calculated from data of downward and upward solar radiation and downward and upward longwave radiation. Vapor pressure was calculated from the air temperature and relative humidity using the Goff-Gratch equation (Hayashi 1988). Wind direction was divided into 16 sections and indicated by cardinal directions (e.g., N, NEE). Data gaps in global solar radiation and air temperature were filled with data obtained using the backup system after instrumental correction. When data of both observation sets were unavailable, AMeDAS data obtained at Kawaguchiko were used (see Appendix). The data gaps for other meteorological elements were not filled.

Results

Monthly and annual means of the daily global solar radiation, air temperature, vapor pressure and wind velocity and monthly and annual precipitation are given in Table 1 . The averages were calculated for the nine years from 2000 to 2008 . The available data rates for vapor pressure, wind velocity and wind direction were 99 %, 97 % and 99 %, respectively. Monthly precipitation in May, June and August 2008 was unavailable because of a failure of the data logger. Thus, precipitation data for 2008 were excluded in statistical processing. Less than 90 % of data for net radiation in 2000 and 2008 were available; thus, net radiation data for 2000 and 2008 were excluded in statistical processing. The resulting availability of net radiation data was 99 %.

Table 1 . Monthly and annual mean meteorological data for the Fujiyoshida forest meteorology research site.

	Global solar radiation	Air temperature	Precipitation	Vapor pressure	Wind velocity
Month	MJ $m^{-2}d^{-1}$	℃	mm $month^{-1}$	kPa	m s^{-1}
January	10.6	-1.4	101	0.36	2.3
February	13.4	-0.7	68	0.38	2.3
March	16.3	2.5	113	0.48	2.5
April	18.1	8.1	104	0.74	2.4
May	17.8	12.3	152	1.15	2.1
June	16.2	16.2	163	1.59	1.8
July	16.7	20.1	207	2.01	1.8
August	16.7	20.4	252	2.07	1.8
September	12.6	17.0	298	1.73	1.8
October	10.8	11.3	316	1.17	1.9
November	9.8	6.3	110	0.74	2.1
December	9.5	1.2	73	0.46	2.2
Annual	14.1	9.5	1955	1.07	2.1

Data are nine-year averages from 2000 to 2008 except for precipitation. Precipitation is only the eight-year average from 2000 to 2007 because of data unavailability.

Global solar radiation

Annual mean daily global solar radiation ranged from 12 . 9 $MJm^{-2}d^{-1}$ in 2003 to 14 . 9 $MJm^{-2}d^{-1}$ in 2004 , and the nine-year average was 14 . 1 $MJm^{-2}d^{-1}$. The nine year average of monthly mean daily global solar radiation ranged between 9 . 5 and 18 . 1 $MJm^{-2}d^{-1}$ and was lowest in December and highest in April. The coefficient of variation was largest in July (0.34) and the monthly mean daily global solar radiation in July varied from 10.9 $MJm^{-2} d^{-1}$ in 2003 to 21.8 $MJm^{-2} d^{-1}$ in 2001.

Net radiation

Annual mean daily net radiation ranged from 7.6 $MJ m^{-2} d^{-1}$ in 2003 to 8.5 $MJm^{-2} d^{-1}$ in 2004, and the seven-year average was 8.1 $MJm^{-2} d^{-1}$.

Air temperature

Annual mean air temperature ranged from 9.1 ℃ in 2001 to 10.4 ℃ in 2004, and the nine-year average was 9.5 ℃. The nine-year averages of monthly mean air temperature were low in January (-1.4 ℃) and February (-0.7 ℃). The lowest monthly mean air temperature was -2.7 ℃ in 2008. Annual lowest air temperatures were less than -10 ℃ excluding 2002 and 2007, and the lowest during the observation period was -12.6 ℃ in 2001. The nine-year averages of monthly mean air temperature were high in July (20.1 ℃) and August (20.4 ℃). Annual highest air temperatures exceeded 30 ℃ excluding 2005, and the highest during the observation period was 34.2 ℃ in 2000.

Precipitation

Annual precipitation ranged from 1578 mm in 2007 to 2534 mm in 2004, and the eight-year average was 1955 mm. The eight-year averages of monthly precipitation were low in February (68 mm) and December (73 mm). The eight-year averages of monthly precipitation were high in September (298 mm) and October (316 mm). The lowest monthly precipitation for the eight years from 2000 to 2007 was 1.5 mm in December 2000, and the highest was 962 mm in October 2004.

Vapor pressure

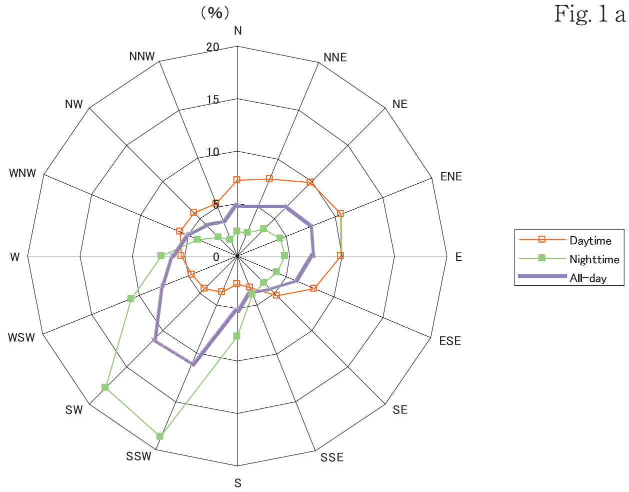
Annual mean vapor pressure ranged from 1.02 kPa in 2001 to 1.17 kPa in 2006, and the nine-year average was 1.07 kPa. The nine-year averages of monthly mean vapor pressure were lowest in January (0.36 kPa) and highest in August (2.07 kPa). The lowest monthly mean vapor pressure for the nine years was 0.28 kPa in February 2000 and 2008, and the highest was 2.28 kPa in August 2006.

Wind velocity

Annual mean wind velocity ranged from 1.9 ms^{-1} in 2008 to 2.3 ms^{-1} in 2003, and the nine-year average was 2.1 ms^{-1}. Most monthly means of wind velocity in summer from June to October were less than 2 ms^{-1}, and those in winter were more than 2 ms^{-1}. All monthly means of wind velocity in April exceeded 2.1 ms^{-1}, and all those in June were less than 2.0 ms^{-1}.

Wind direction

Wind roses are shown in Figs. 1 a and b. The prevailing wind direction through the year was south-southwest,



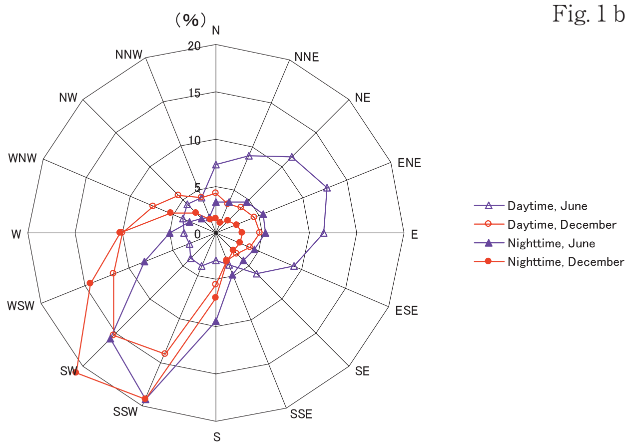


Figure 1. Wind roses for Fujiyoshida created with 9-year data classified in; a) Daytime, Nighttime and All-day; and b) Daytime and Nighttime for June and December

and that during the day and that at night were east-northeast and south-southwest, respectively (Fig. 1 a). The prevailing wind direction changed seasonally (Fig. 1 b). Monthly prevailing wind directions at night were southwest or south-southwest. In contrast, those during the day were east-northeast and east from April to November and northwest and west-northwest in the other months.

Discussion

A hythergraph is often used as a climatic diagram. Hythergraphs for the Fujiyoshida site and two nearby AMeDAS stations (Kawaguchiko and Yamanaka) are shown in Fig. 2. The locations of the AMeDAS stations are given in Table 2. Fujiyoshida is approximately 5 and 7 km distant from Kawaguchiko and Yamanaka, respectively. The nine-year averages of annual mean air temperature and annual precipitation from 2000 to 2008 (eight-year average of annual precipitation from 2000 to 2007) at Kawaguchiko and Yamanaka were

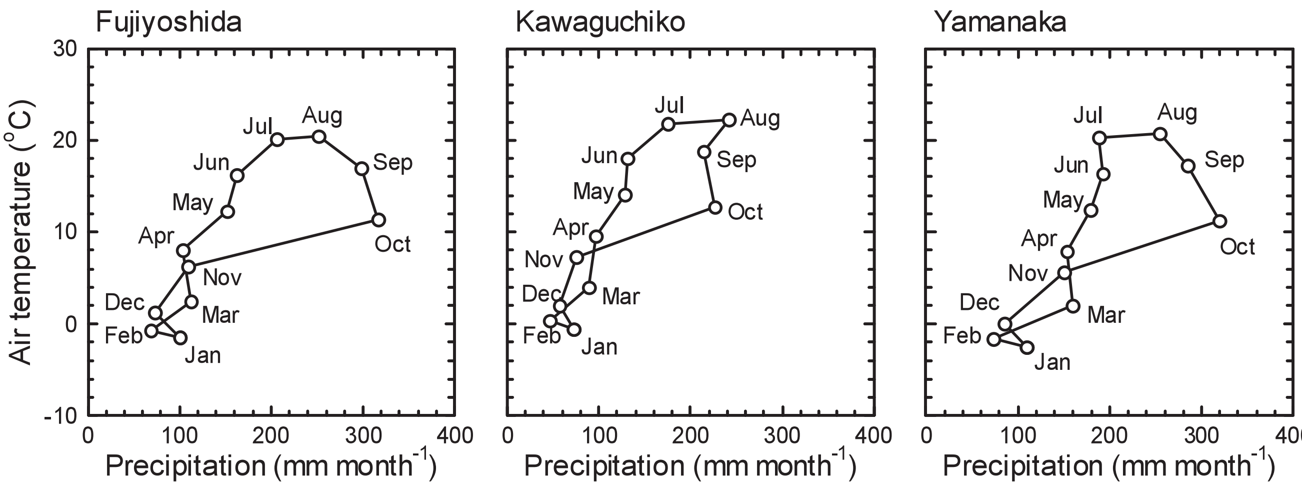


Figure 2 . Hythergraphs for Fujiyoshida and two nearby AMeDAS stations: Kawaguchiko and Yamanaka.

Table 2 . Locations of the Fujiyoshida forest meteorology research site and nearby AMeDAS stations and weather stations.

Station	Latitude	Longitude	Altitude (m)	Organization
Yamanaka	35°26.2'	138°50.2'	992	JMA (AMeDAS)
Fujiyoshida	35°27.3'	138°45.7'	1030	FFPRI
Kawaguchiko	35°30.0'	138°45.6'	860	JMA (AMeDAS)
Kofu	35°40.0'	138°33.2'	273	JMA (weather station)
Shizuoka	35°58.5'	138°24.2'	14	JMA (weather station)

AMeDAS: Automated Meteorological Data Acquisition System

11 . 0 ℃ and 1556 (1561) mm, and 9 . 2 ℃ and 2151 (2177) mm, respectively. The shape of the hythergraph for Fujiyoshida was similar to that for Yamanaka but different from that for Kawaguchiko. Seasonal changes in air temperature at Kawaguchiko and Yamanaka were similar to those at Fujiyoshida. However, precipitation at Kawaguchiko differed from that at Fujiyoshida and that at Yamanaka; the highest monthly precipitation was in October at Fujiyoshida and Yamanaka, and in August at Kawaguchiko. Although Kawaguchiko is closer to Fujiyoshida than is Yamanaka, climatic characteristics of Kawaguchiko differ from those of Fujiyoshida, possibly owing to altitude and microtopography.

Global solar radiation is compared among Fujiyoshida and the nearby weather stations of Shizuoka and Kofu (Fig. 3). The locations of the weather stations are given in Table 2 . Monthly means in Fig. 3 were calculated using data from 2000 to 2008 . Annual mean daily global solar radiation at Shizuoka and Kofu is 14 . 0 and 14 . 5 MJ $m^{-2} d^{-1}$, respectively. The seasonal change in global solar radiation at Fujiyoshida was similar to that at Shizuoka and Kofu; however, monthly means from July to October at Fujiyoshida were much lower than those at other weather stations. The frequency of rainy days, which are

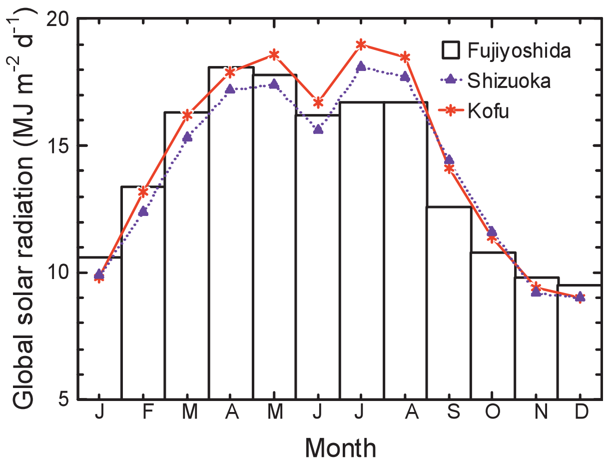


Figure 3 . Seasonal changes in monthly global solar radiation at Fujiyoshida and two nearby weather stations: Shizuoka and Kofu.

the elapsed days on which the rain gauge detects more than 0 . 5 mm precipitation, and wetting days, which are the elapsed days on which the wetting sensor detects the wetting, in 2006 and 2007 at Fujiyoshida are shown in Fig. 4 . Rainy days were frequent in April, June and September, while wetting days were frequent from July to October. Fujiyoshida has a high elevation, and it is expected that the site is covered with fog and cloud. The many wetting days in summer and autumn indicate the possibility of fog and cloud. This condition may be the reason for the low solar radiation in summer and autumn.

The Chikugo model (Uchijima and Seino 1985) is a well-known model that estimates the climatic net primary production (NPP). The climatic NPP at Fujiyoshida estimated from the observation data was 18 . 9 tDWha $^{-1}$ y^{-1} . This was large compared with the estimations of Uchijima and Seino (1985). Uchijima and Seino (1985) made their calculations using the estimated net radiation.

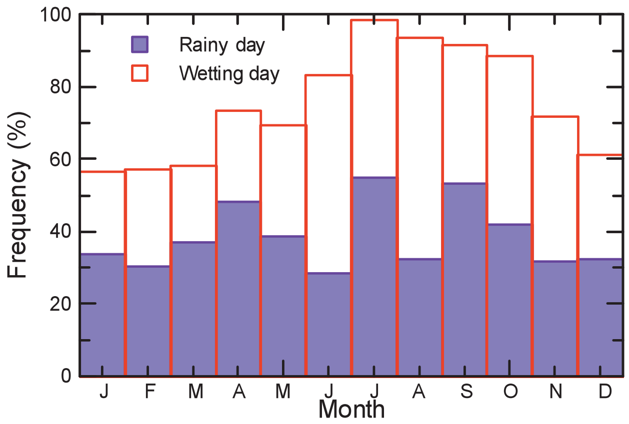


Figure 4 . Frequencies of monthly rainy days and wetting days in 2006 and 2007 .

The climatic NPP at Fujjiyoshida obtained from the estimated net radiation according to Uchijima and Seino (1985) was 89 % as large as that determined from observed net radiation. The difference in net radiation affected the estimated climatic NPP. The Miami model proposed by Lieth (1973) estimates the climatic NPP using air temperature or precipitation. The climatic NPP estimated from air temperature and precipitation employing the Miami model was 13 . 6 and 21 . 7 tDWha $^{-1}$ y $^{-1}$, respectively. The climatic NPP estimated from air temperature was much less than that estimated from precipitation. These results suggest that the conditions for vegetation production are sufficient in terms of radiation and precipitation but possibly insufficient in terms of air temperature.

Adopting Koppen-Geiger classification (Kottek et al. 2006), the climate at the Fujiyoshida site belongs to the temperate zone (Cfa). The Fujiyoshida site is located east of the Eurasian Continent and in a monsoon area, where there is much rain in general. Sekiguchi (1959) classified the area around Fujiyoshida as the coast of the Pacific Ocean, where there are many rainy days in summer and fine days in winter. Although climatic characteristics of the Fujiyoshida site are basically representative of the Koppen-Geiger and Sekiguchi classification, air temperature was slightly low compared with data for the surrounding area, and global solar radiation in summer was low. This may be partly explained by the high elevation.

Conclusion

Although air temperature was slightly low and solar radiation in summer was low because of high elevation, the climate of the Fujiyoshida site is such that there is sufficient precipitation and radiation for the growth of vegetation. Carbon accumulation is presently being evaluated employing micrometeorological and biometric methods. Data of actual vegetation production will clarify the effects of the climate and other site conditions including soil and vegetation type.

Acknowledgments

We are grateful to the staffs of the Yamanashi Institute of Environmental Science and to Dr. Motomu TODA (Hokkaido University) for assistance in managing the Fujiyoshida site. The meteorological data of the AMeDAS and weather stations were supplied by the Japan Meteorological Agency. This study was supported in part by the Global Environment Research Fund (B 3 :FY 2000 - 2002 , S 1 :FY 2002 - 2006); the Global Environment Research Account (FY 2007 - 2011) of the Japanese Ministry of the Environment; a project research fund (Environment Research: FY 2006 - 2009) from the Japanese Ministry of Agriculture, Forestry and Fisheries; and research grants (# 199903 :FY 1999 - 2002 , # 200303 : FY 2003 - 2005) from the Forestry and Forest Products Research Institute.

References

Han Q, Kawasaki T, Nakano T, Chiba Y (2004) Spatial and seasonal variability of temperature response of biochemical photosynthesis parameters and leaf nitrogen content within a *Pinus densiflora* crown. Tree Physiol 24 : 737 - 744

Hayashi M (1988) Measurement of humidity. In: The society of agricultural meteorology of Japan, Kanto affiliate (eds) Instruments and methods for agricultural meteorology. Association for advancement of agricultural science, Tokyo, pp 51 - 81 (in Japanese only)

Kottek M, Grieser J, Beck C, Rudolf B. Rubel F (2006) World Map of the Koppen-Geiger climate classification updated. Meteorol Zeitschrift 15 : 259 - 263

Lieth H (1973) Primary production: Terrestrial ecosystem. J of Human Ecology 1 : 303 - 332

Ohtani Y, Mizoguchi Y, Watanabe T, Yasuda Y (2005) Parameterization of NEP for gap filling in a cool-temperate coniferous forest in Fujiyoshida, Japan. J Agric Meteorol 60 (5): 769 - 772

Ohtsuka T, Goto T, Sugita M, Nakashima T, Ikeguchi H (2003) The origin of pine forest on Ken-marubi lava flow on the lower slopes of Mt. Fuji. Veg Sci 20 : 43 - 54 (in Japanese with an English abstract)

Sekiguti (1959) Climatic regions in Japan. Tokyo Geog Papers 3 : 65 - 78 (in Japanese with an English abstract)

Tanabe H, Abe Y, Nakano T (2004) Nitrogen use by Pinus densiflora trees growing on a Mt. Fuji lava flow. J Fore Res 9 : 249 - 54

Uchijima Z, Seino H (1985) Agroclimatic evaluation on net primary productivity of natural vegetations (1) Chikugo model for evaluating net primary productivity. J Agr Met 40 (4): 343-352

Appendix: Gap filling method using AMeDAS data

1. Air temperature

AMeDAS data are supplied as hourly data. We converted the hourly data to half-hourly data using the following equations.

$$Taf(i) = Ta(i) + (Ta(i+1) - Ta(i)) \times 0.25$$

$$Tal(i) = Ta(i) + (Ta(i+1) - Ta(i)) \times 0.75$$

Ta (i): hourly mean air temperature at time i

*Ta*f (i): half-hourly mean air temperature in the first half of time i (e.g., 10:00 - 10:30)

*Ta*l (i): half-hourly mean air temperature in the second half of time i (e.g., 10:30 - 11:00)

The relationship between Fujiyoshida data and AMeDAS data (*Ta*f and *Ta*l) was found and data gaps were filled with data calculated using the expression.

2. Global solar radiation

AMeDAS supply sunshine duration and not global solar radiation. We estimated global solar radiation from sunshine duration and solar radiation at the top of the atmosphere according to Kondo (1994).

References

Kondo J (1994) Solar radiation and atmospheric radiation. In: Meteorology in water environment. (eds) Kondo J, Asakura Publishing Co., Ltd., Tokyo pp 55-92 (in Japanese only)