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Energy Conversion and Management 47 (2006) 2859–2866
ENERGY CONVERSION & MANAGEMENT
www.elsevier.com/locate/enconman

Trends of the global radiation and sunshine hours in 1961–1998 and their relationships in China

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Received 20 September 2005; accepted 22 March 2006
Available online 18 May 2006

Abstract

Trends of the yearly global radiation E_g, annual sunshine hours S, yearly precipitation P and yearly averaged air temperature T at 51 stations in 1961–1998 in China were detected, and the significance test method was the F-test. A total of 47 stations showed decreasing trend in the E_g series of which 35 passed the F-test at the 5% significant level. At 42 stations, the trend of S was also decreasing, and 36 of them passed the F-test at the 5% significant level. The P series did not change largely in 1961–1998 and at 37 stations showed a positive trend, while the positive trend or reduced trend at 39 stations did not pass the F-test at the 25% significant level. The positive trend of the T series was shown at 49 stations, of which 29 passed the F-test at the 1% significant level. In the yearly scale, the empirical relationship between E_g and S at any station was very low because the length of the E_g series was too short. When using all the data at the used 51 stations together to simulate E_g, the results were good. Using the longitude λ, latitude ϕ and altitude H, or/and P and T, of the used stations to adjust the parameters a and b of the Angström model, respectively, or just to adjust the parameter a, the results will be better. The parameter b of the Angström model was little affected by the geographical position of the used stations. At last, a simple equation is recommended to use for simulation of the yearly global radiation in China.

Keywords: Angström model; F-test; Precipitation; Air temperature

1. Introduction

Global radiation, E_g, the total short wave irradiance from the sun and sky, is the principal energy source for physical, biological and chemical processes, such as snow melt, plant photosynthesis, evapotranspiration, crop growth etc. and is also a variable needed for biophysical models to evaluate the risk of forest fires, hydrological simulation models and mathematical models of natural processes [1]. Any significant and widespread change in E_g is, therefore, likely to be of major importance for agricultural production as well as for climate change and the direct exploitation of solar energy [2]. Decreasing trends of the observed E_g have been reported worldwide over the past several decades, such as the report from Germany (e.g. [3,4]), from the United States

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0196-8904/$ - see front matter © 2006 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enconman.2006.03.029

(e.g. [4,5]), from the former Soviet Union (e.g. [6]), from Finland (e.g. [7]) and from Estonia (e.g. [8]). The most probable cause of the reduction is that increases in man made aerosols and other air pollutants have changed the optical properties of the atmosphere, in particular those of clouds [2]. Thus, many researchers have used the reduction of E_g to analyze atmospheric pollution (e.g. [9,10]).

Many empirical relationships have been found between monthly daily mean or daily global radiation and some basic climatic variables such as sunshine hours, air temperature and so on (e.g. [11–14]). Are the empirical relationships still present in the yearly scale? Because the yearly global radiation E_g, the yearly sunshine hours S, the yearly precipitation P and the yearly averaged air temperature T vary with global warming, is there an empirical relationship among these long term yearly series? This is the main purpose of the paper, to investigate this question.

2. Data and methods

Yearly data were calculated from the daily data provided by the Chinese National Meteorological Center. These data included yearly global radiation E_g (MJ m^{-2}), annual sunshine hours S (h), annual precipitation P (mm) and yearly averaged air temperature T (°C), which were measured at 51 stations (Table 1) from 1961 to 1998. There are more than 700 reference stations where the S, P and T are measured, but there are only 98 stations that measure global radiation in the China Mainland. Here, the data at 51 global stations are used. That is to say, 47 stations at which the data in 1961–1998 are partly absent or the quality of the observed data is low are not chosen.

Linear regressions of each of the time series of these variables at the used 51 stations over the period 1961–1998 were calculated in order to detect trends. The F-test method [15] was used to evaluate the significance of the trend.

The basic Angström model [16] and some revised models were validated using the yearly sunshine hours and/or some other variables.

The basic Angström model has the form as

$$\frac{E_g}{E_0} = a + b\frac{S}{S_0}, \quad (1)$$

where E_g is the yearly global radiation (MJ m^{-2}), E_0 is the yearly extra terrestrial solar radiation (MJ m^{-2}), S is the actual annual sunshine hours (h), S_0 is the potential annual sunshine hours (h) and a and b are empirical parameters. The revised Angström models will be shown in the following parts.

Table 1
Detail information of the used 51 stations in China

Stations	Latitude (N)	Longitude (E)	Altitude (m)	Stations	Latitude (N)	Longitude (E)	Altitude (m)	Stations	Latitude (N)	Longitude (E)	Altitude (m)
Heihe	127°27′	50°15′	166.4	Yinchuan	106°13′	38°29′	1111.4	Zhengzhou	113°39′	34°43′	110.4
Haerbin	126°46′	45°45′	142.3	Taiyuan	112°33′	37°47′	778.3	Yichang	111°18′	30°42′	133.1
Alatai	88°05′	47°44′	735.3	Changchun	125°13′	43°54′	236.8	Wuhan	114°08′	30°37′	23.3
Yining	81°20′	43°57′	662.5	Yanji	129°28′	42°53′	176.8	Chongqing	106°28′	29°35′	259.1
Urumqi	87°37′	43°47′	917.9	Shenyang	123°27′	41°44′	42.8	Guiyang	106°43′	26°35′	1074.3
Tulufan	89°12′	42°56′	34.5	Peking	116°17′	39°56′	54	Guilin	110°18′	25°19′	194.4
Kashi	75°59′	39°28′	1288.7	Tianjin	117°04′	39°05′	2.5	Ganzhou	114°57′	15°51′	123.8
Ruoqiang	88°10′	39°02′	888.3	Jinan	116°59′	36°41′	51.6	Gushi	115°40′	32°10′	57.1
Hetian	79°56′	37°08′	1374.6	Lasa	91°08′	29°40′	3648.7	Nanjing	118°48′	32°00′	8.9
Hami	93°31′	42°49′	737.2	Yushu	97°01′	33°01′	3681.2	Shanghai	121°29′	31°24′	3.5
Tunhang	94°41′	40°09′	1139	Changdu	97°10′	31°09′	3306	Hangzhou	120°10′	30°14′	41.7
Minqin	103°05′	38°38′	1367	Chengdu	104°01′	30°40′	506.1	Nanchang	115°55′	28°36′	46.7
Geermu	94°54′	36°25′	2807.6	Emeishan	103°20′	29°31′	3047.4	Fuzhou	119°17′	26°05′	84
Xining	101°46′	36°37′	2261.2	Tengchong	98°30′	25°01′	1654.6	Guangzhou	113°19′	23°08′	6.6
Lanzhou	103°53′	36°03′	1517.2	Kunming	102°41′	25°01′	1891.4	Shantou	116°41′	23°24′	1.1
Erlianhaote	111°58′	43°39′	964.7	Mengzi	103°23′	23°23′	1300.7	Nanning	108°21′	22°49′	73.1
Datong	113°20′	40°06′	1067.2	Xian	108°56′	34°18′	397.5	Haikou	110°21′	20°02′	13.9