A Research of Calculation Method of Daily Solar Radiation in Ningxia Region

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Abstract

Through observation data of daily solar radiation of Yinchuan station of Ningxia, using linear relationship between observation values of solar radiation and extraterrestrial radiation and relative sunshine duration and daylength, we obtained regional coefficients a_s =0.18, b_s =0.62 by their linear correlation of past five years(1981-1985). Using the same method, coefficients of Guyuan region were confirmed too. Applying regional coefficients to be gotten and calculation formula of solar radiation, we validated daily solar radiation of two years(1986-1987) of Yinchuan station and four years(1991-1994) of Guyuan station through comparison with observation data, the results showed there were higher relationship because of the high square error R^2=0.94 in Yinchuan and R^2=0.85 in Guyuan. Simulation effect was evaluated through those methods called mean bias error, mean absolute bias error, root mean square error, mean absolute percentage error on solar radiation of Yinchuan(1973-2006) and Guyuan(1986-2006) stations. Results showed the root mean square error was large slightly, mean absolute bias error was not up to 13% and 17% in Yinchuan station and Guyuan station respectively. We estimated daily solar radiation of Yongning station using the related formula of solar radiation and regional coefficients and comparing with daily solar radiation of observation of Yinchuan of the past twelve years(1989-2000). The results showed there were good linear relationships in the twelve years, the minimum of correlation coefficient R^2 equaled 0.88 in twelve years.

Key words: Local coefficient Daily solar radiation Extraterrestrial radiation Relative sunshine duration

1.Introduction

In order to develop and apply climate source, the method that local solar energy is evaluated becomes a kind of exigent need. Most of paper on solar energy assessment method is to resolve a application of daily solar radiation as the basic input variables in crop modeling[1-4]. But the method how to confirm local coefficients in calculation formula is not introduced detailedly. In Ningxia region there are 26 weather stations, but at only two stations daily solar radiation was observed. In this paper, by classical simulation calculation method, different local coefficients were obtained for calculating daily solar radiation of north and south in.Ningxia region, and then simulated daily solar radiation of Yongning station in Ningxia for past twelve years(1989-2000). This simulation method is expected to be able to apply in other stations.

2. Method and Data

Though calculation formula of daily solar radiation in DeBoer et. al (2005)'s paper was quoted, as form (1) below.

$$Rs = (as + bs\frac{n}{N})Ra \qquad (1)$$

Where R_s: solar or shortwave radiation [MJ m^{-2} day^{-1}]; n: actual duration of sunshine [hour], is duration of bright sunshine observed by weather station as a normal meteorological factor; N : maximum possible duration of sunshine or daylight hours [hour], is daylength and need to calculate; n/N : relative sunshine duration. R_a : extraterrestrial radiation [MJ m^{-2} day^{-1}], is available through calculation; a_s : Regression constant, expressing the fraction of extraterrestrial radiation reaching the earth on overcast days (n = 0); $a_s + b_s$: fraction of extraterrestrial radiation reaching the earth on clear days ($n = N$). How to calculate N and Ra detailedly, please refer DeBoer et. al (2005)'s paper.

All relative meteorological data in calculation are from observation value of weather stations of Ningxia. Local coefficients a_s and b_s in this formula were confirmed and validated through applying observation data of daily solar radiation of Yinchuan and Guyuan stations in Ningxia. In order to decide coefficient a_s and b_s of local regions, we applied daily data of five years' solar radiation observed from 1981 to 1985 in Yinchuan using a linear relationship relating solar radiation to extraterrestrial radiation and sunshine hours. Fig.2-1 shows a linear relation between solar radiation (R_s) and the formula relating to extraterrestrial radiation (R_a) and sunshine hours(n) and daylength(N) in Yinchuan after deleting one or two extreme values.Through this relationship we were able to obtain values of a_s =0.18 and b_s =0.62 and use them to calculate solar radiation for other counties near Yingchuan in Ningxia.

From above relationship by iterating test local coefficients a_s =0.18 and b_s =0.62 were obtained and validated for two-year's results in 1986 and 1987 by comparing with measured radiation. Fig.2-2 showed there was a good agreement between calculated and measured values and approached 1:1 line, so we can consider using a_s and b_s values to calculate solar radiation of other regions near Yinchuan station in Ningxia.

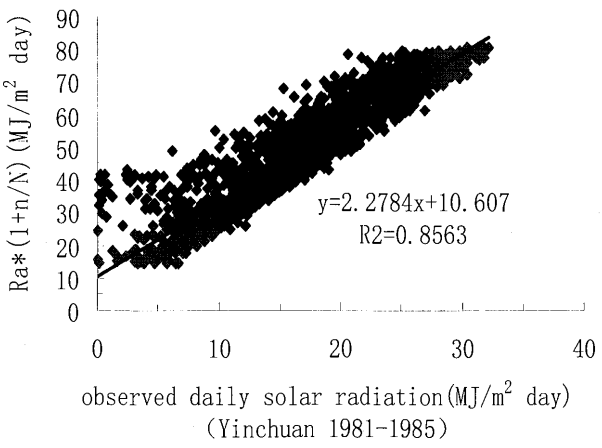

Fig.2-1 Relationship between solar radiation observed and formula

Using the same method, the local coefficients of Guyan station, a_s=0.16 and b_s=.58 were confirmed and validated with observation data of daily solar radiation for four years(1991～1994). Results were showed in Fig.2-3.

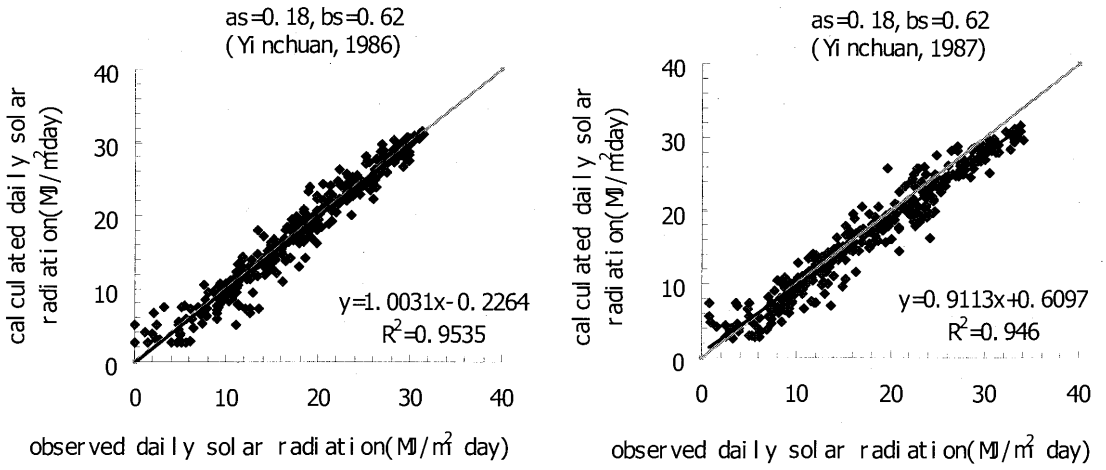

Fig.2-2 Validation of observed and calculated dialy solar radiation in 1986 and 1987 in Yinchuan

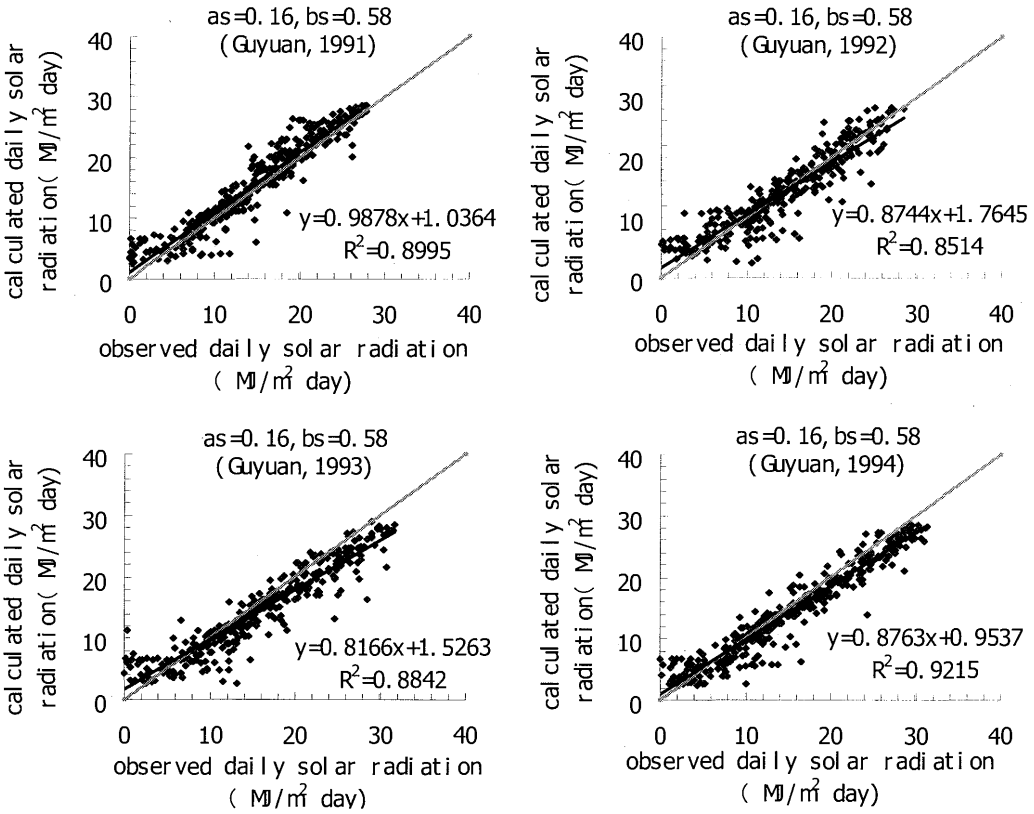

Fig.2-3 Comparison of observation and simulation value of daily solar radiation for four sample years on Guyuan station(1991～1994).

3. Error and Confidence level analysis

3.1 Error analysis

Through validation and error analysis local region coefficients were confirmed and considered that they are available, so two formulas for calculating daily solar radiation were gotten for different climate region of Ningxia below.

$$R_S = (0.18 + 0.62\frac{n}{N})R_a \quad (2)$$

$$R_S = (0.16 + 0.58\frac{n}{N})R_a \quad (3)$$

Where, form (2) is appropriate north and middle regions of Ningxia, form (3) is appropriate south Guyuan region of Ningxia. Applying above two formulas, we simulated historic value of daily solar radiation of Yinchuan(1973-2006) and Guyuan(1986-2006) and analyzed mean bias error(MBE MJ m^{-2} d^{-1}), mean absolute bias error(MABE MJ $m^{-2}d^{-1}$), root mean square error(RMSE MJ m^{-2} d^{-1}), mean absolute percentage error(MAPE %).Error analysis results showed in table 3.1-(1) below.

$$MBE = \frac{1}{n}\sum_{i=1}^{n}(R_{sim} - R_{obs})$$

$$MABE = \frac{1}{n}\sum_{i=1}^{n}|(R_{sim} - R_{obs})|$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(R_{sim} - R_{obs})^2}$$

$$MAPE = \frac{100}{n}\sum_{i=1}^{n}|R_{sim} - R_{obs}| \Big/ \frac{1}{n}\sum_{i=1}^{n}R_{obs}$$

Because Guyuan station was set up in 1986, so data showed from this year.

Where, Rsim and Robs are simulation and observation value, n is the number of sample years.

Error analysis descried MBE、MSBE、RMSE are more approach for two stations, MBE in most years in Yinchuan station is positive, in Guyuan station is negative. It shows simulation value is higher than observation value in Yinchuan, is lower in Guyuan station. MAPE of Yinchuan is lower than Guyuan, the maximize is up to 13% and 17% in Yinchuan station and

3.2 Confidence Level test

Confidence level T-test was done on simulation and observation value of daily solar radiation for five years(1986-1990) in Guyuan station, as table 3.2-(1) below. According to this T-test table, when confidence level was set at α=0.05, T value is 1.96. For the five years absolute value T is lower than 1.96, so they have obvious correlation between simulation and observation value. Simulation results are better.

Table 3-(1) Various error test of daily solar radiation in

Yinchuan(1973～2006) and Guyuan(1986～2006) stations

Yinchuan station	MBE	MABE	RMSE	MAPE(%)	Guyuan station	MBE	MABE	RMSE	MAPE(%)
1973	1.4	1.8	2.5	10.7					
1974	1.4	1.7	2.3	9.9					
1975	0.7	1.4	1.9	8.6					
1976	0.5	1.4	2.3	8.4					
1977	0.3	1.3	1.8	7.7					
1978	0.8	1.3	1.9	7.8					
1979	0.2	1.4	1.9	8.2					
1980	1.5	1.9	2.8	11.9					
1981	1.3	1.8	2.5	11.5					
1982	0.7	1.5	2.1	9.1					
1983	0.8	1.5	2.2	9.6					
1984	0.3	1.3	1.8	7.6					
1985	-0.2	1.7	2.2	8.3					
1986	-0.3	1.2	1.7	7.2	1986	-0.2	2.5	3.9	16.5
1987	-1.0	1.7	2.2	9.9	1987	-0.4	1.9	2.4	11.9
1988	-0.1	1.6	2.1	9.5	1988	0.3	1.9	2.5	13.5
1989	0.6	1.4	1.9	9.1	1989	0.2	2.0	2.6	14.2
1990	1.6	1.9	2.6	12.1	1990	0.0	1.7	2.4	11.5
1991	0.3	1.4	2.0	8.4	1991	1.0	1.8	2.4	12.4
1992	0.4	1.8	3.1	11.6	1992	0.3	2.0	2.8	14.5
1993	-0.1	1.4	2.3	8.5	1993	-1.0	2.3	3.3	15.1
1994	1.4	1.8	2.5	10.7	1994	-0.8	1.8	2.4	11.8
1995	1.3	1.7	2.3	9.9	1995	-0.3	1.4	1.7	8.6
1996	0.7	1.4	1.9	8.5	1996	-0.4	1.4	1.8	8.8
1997	0.5	1.4	2.3	8.5	1997	-0.8	1.5	1.9	9.5
1998	0.4	1.3	1.8	7.7	1998	-0.9	1.8	2.0	9.1
1999	0.8	1.3	1.9	7.8	1999	-0.5	1.5	2.0	9.7
2000	0.1	1.4	1.9	8.2	2000	-0.9	1.6	2.2	10.3
2001	1.5	2.0	2.8	12.1	2001	-0.6	1.6	2.3	10.6
2002	1.3	1.8	2.5	11.3	2002	-0.3	1.3	1.8	8.6
2003	0.7	1.5	2.1	9.3	2003	-0.4	1.6	2.1	11.0
2004	0.8	1.5	2.1	9.5	2004	-0.4	1.6	2.1	10.4
2005	0.2	1.3	1.8	7.6	2005	-0.9	1.7	2.1	11.0
2006	-0.2	1.7	2.3	8.3	2006	-1.0	1.5	2.2	11.7

Table 3.1-(1) T-tests value of daily solar radiation for five years

in Guyuan station (1986～1990)

	1986	1987	1988	1989	1990(year)
freedom	728	728	730	728	728
sample size	365	365	366	365	365
T-tests vaule	0.335	0.683	-0.624	-0.328	0.014

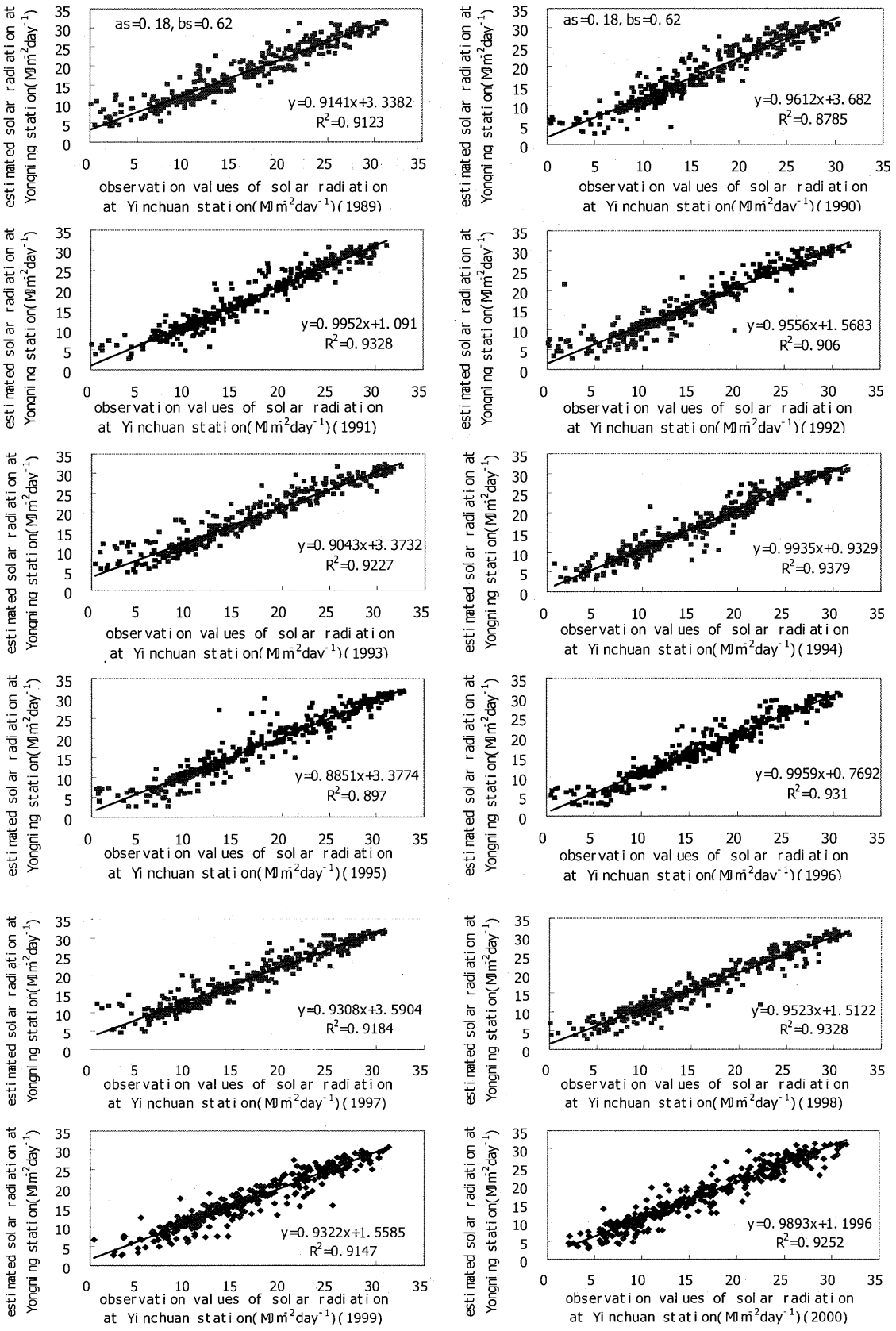

Fig. 4-1 Comparison of estimated solar radiation of Yongning station with observation values of solar radiation of Yinchuan for twelve years(1989-2000)

4. Conclusion

Application calculation formula obtained from Yinchuan station, daily solar radiation of Yongning station was estimated for twelve years(1989-2000). Results were compared with the same time series observation value of Yinchuan as reference in order to avoid extreme value. Results were showed in Fig. 4-1. There is a better line relationship between estimation results of Yongning station and observation of Yinchuan station because minimum square error R^2 reached 0.88, maximum R^2 reached 0.93. It is considered this method is available to estimated daily solar radiation of other regions of Ningxia similar climate condition of Yinchuan.

5. Discussion

There are many methods to calculate daily solar radiation for different regions. On a certain region, a general suggestion is to confirm and validate region coefficients. From two weather stations of Ningxia region, two group better appropriate region coefficients were gotten. A year(1991) was selected random as sample for analysis. Observation value of Yinchuan station was defined as reference standard, relative error of Yongning station was calculated. In 55 days of 365 days relative error was over 20%, in other days, was down 20% except few extreme value. A reason that large difference occurred is thought the quality of observation data, another one is considered observation data suddenly jump to low value range when its change is more stable up or down trend in continuous days. Maybe in initial liner correlation that local coefficients were sought, effect of cloudy or raining days should be eliminated. Obtained relative formula should be applied in a region where there is a similar climate condition so as to insure higher accuracy.

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