PERFORMANCE EVALUATION FOR NET PYRRADIOMETERS

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ABSTRACT

The performance of two models Net Pyrradiometer (model DFY5 and model TBB-1) made in Chna has been tested. We have mainly studied the long-term stability of sensitivity, nonlinearity, temperature dependence, directional response (cosine and azimuth), response time and influence of dome-shape. Sensitivity, response time and influence of dome-shape are tested in outdoor exposure and others are tested on the laboratory test facility. Main error of Net Pyrradiometer is given according to a great of test data and analysis.

1. INTRODUCTION

The net pyrradiometer is intended for the analysis of the radiation balance of Solar and Far infrared radiation, i.e. the net pyrradiometer is used to measure the differences of irradiance between downward and upward radiation including downward short-wave radiation, downward long-wave radiation, upward short-wave radiation and long-wave radiation. There are 50 radiation observation stations used two models Net Pyrradiometer (model DFY5 and model TBB-1) made in China to measure the net irradiance since1990. The principle of instrument is a thermopile detector equipped with polyethylene domes and the voltage output is divided by the sensitivity to obtain irradiance. In order to evaluate the net pyrradiometers performance we have tested the main specifications. Main error for net pyrradiometers are concluded according to a great of test data and analysis.

2. PERFORMANCE TEST

Nine instruments are tested, which serial numbers are 007, 008, 015, 047 for model DFY5 and 9606, 9607, 9608, 9609, 9610 for model TBB-1. In the measurements we use a PC in conjunction with data logger and output of instrument can be measured and processed automatically.

2.1 Sensitivity and Long-term Stability

Net pyrradiometr No.84001 (model CN-11, from EKO Japan) is used as a reference instrument. The test and reference instruments are put on the platform of roof. Data are collected every two minutes. Sensitivity is tested in different seasons and weather condition(clear day, nebulous, cloudy and less than 5 m/s wind speed). From the measurements we have got two sensitivity for the net pyrradiometer. That is daytime sensitivity(total-wave sensitivity) and nighttime sensitivity(longwave sensitivity).

The experiment is covered 8 months and the results are given in Fig.1, Fig2, Fig3 and Fig4. It shows that the daytime sensitivity is very dispersed which occurs at the condition of lower solar elevation angle(less than 30°) and lower temperature (less than 0℃). The maximum relative error is about 16% for model TBB-1 at the daytime. This is a combined error caused by nonlinearity, temperature dependence, directional response, zero drift of the instrument and et al.

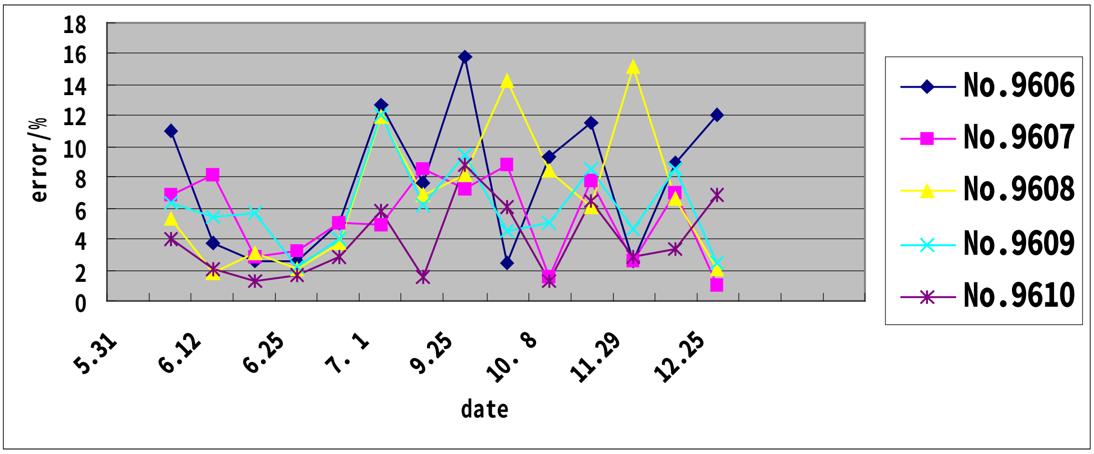

Fig 1. Daytime Sensitivity Change for Model TBB-1 Net Pyrradiometer

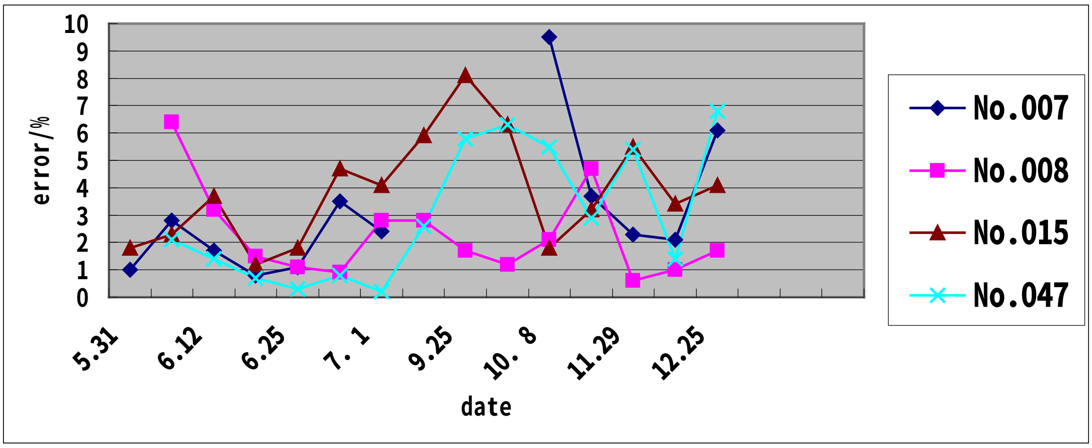

Fig2. Daytime Sensitivity Change for Model DFY5 Net Pyrradiometer

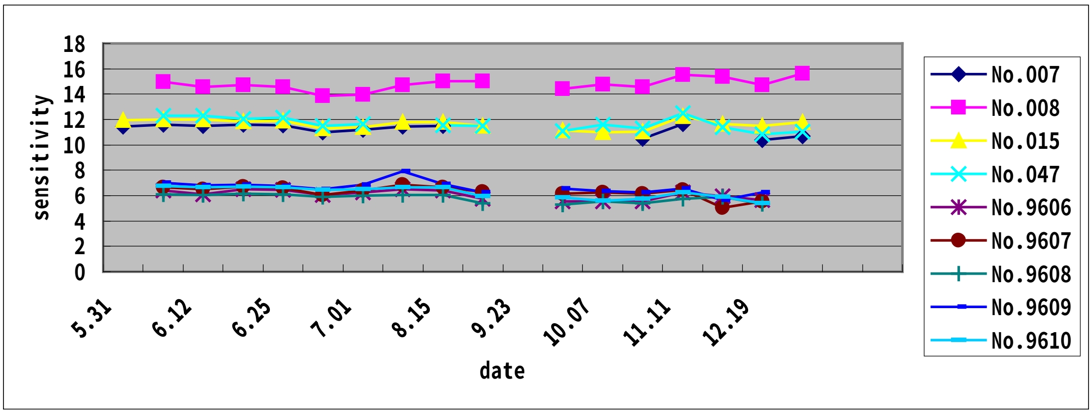

Fig 3. **Long-term Stability of Daytime Sensitivity over 8 Months**

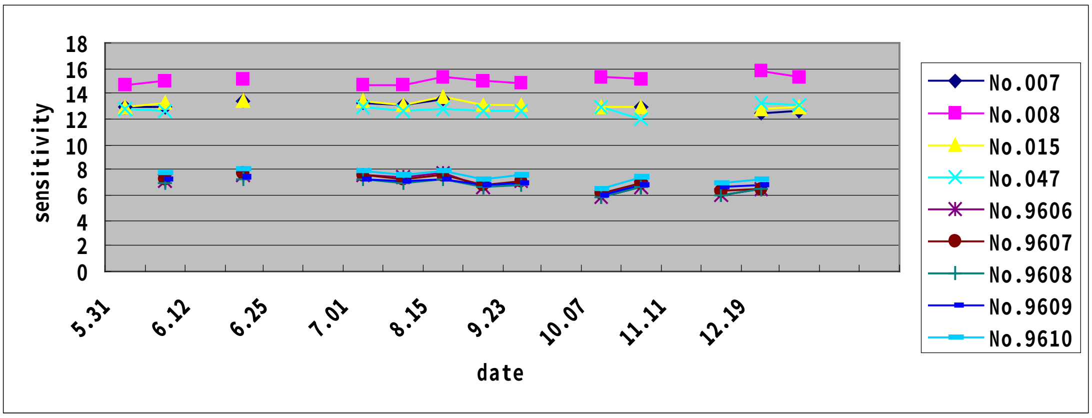

Fig 4. Long-term Stability of Nighttime Sensitivity over 8 Months

Nonlinearity is tested in the laboratory. The test facility consists of mechanism and a solar simulator that the spectrum components do not change with irradiance. Test point is respectively at irradiance of 250, 500, 750 and 1000 W/㎡. Nonlinearity is given by $\delta_L=(V/V_{500}-1)\times 100\%$. In the formula V is the output of net pyrradiometer and V_{500} is the output of net pyrradiometer when the irradiance is 500W/㎡. From the results we know that the maximum nonlinearity error is 2.3% and is in the lower irradiance.

2.3 Temperature Dependence

Temperature dependence is tested on the laboratory test facility with a temperature chamber. We change the temperature in the chamber while the irradiance is unchanged and then the output of instrument is measured. The temperature test point is respectively at -20℃, 0℃, 20℃, 40℃ while the irradiance is 1000W/㎡. Temperature error is given by $\delta_T=(V_T/V_{20}-1)\times 100\%$. In the formula V_T, V_{20} is respectively output of instrument when the temperature is T and 20℃. From the results the temperature error is within ±5% .

2.4 Directional Response

Directional response can be divided into cosine response and azimuth response

2.4.1 Cosine Response

Cosine response test is made use of studying the directional character of incident beam. The irradiance is adjusted to 1000 W/㎡ on the laboratory test facility. Fist the output of instrument(V_0) is tested in $\theta=0°$ (θ is zenith angle), namely solar elevation angle **h**=90° , then the solar elevation angle **h** is adjusted to 80° to measure the output of instrument. Each angle of measurement is at 90° , 80° , 70° ,60° ,50° ,40° ,30° ,20° ,10° . The output of instrument for solar elevation angle 90° ($\theta=0°$) is tested again.

Cosine response error is calculated by formula $\delta_\theta=(V_\theta/V_i-1)\times 100\%$. In the formula the relation between θ and h is h=90° -θ, V_θ is the output of instrument at θ, and $V_i= V_0\cdot\cos\theta$ is an ideal value at θ and V_0 is the average of two outputs of instrument at θ=0° . The results are listed in the table 1. The maximum error is 15.65% at solar elevation angle 10° .

Table 1. The Relative Error for Cosine Response（%）

No.	Model	10°	20°	30°	40°	50°	60°	70°	80°
007	DFY5	-15.65	-9.02	-4.67	-2.96	-1.88	-1.33	-0.01	0.29
008	DFY5	-15.62	-7.80	-4.29	-1.35	-0.41	0.21	0.47	0.41
015	DFY5	-3.93	-0.43	0.57	0.80	0.29	-0.02	0.25	0.57
047	DFY5	-7.53	-2.98	0.42	0.37	0.14	-0.08	0.86	0.70
9606	TBB-1	0.39	-0.39	0.06	-0.51	-0.35	-1.17	-1.98	-1.88
9607	TBB-1	-1.62	-3.39	-3.79	-2.42	1.34	2.38	1.77	0.63
9608	TBB-1	5.19	2.85	1.57	-0.51	-0.43	-0.24	-0.81	-0.87
9609	TBB-1	-7.68	-3.71	2.27	-1.48	-0.45	-0.79	-0.90	-1.14
9610	TBB-1	2.33	-2.25	-0.16	-0.39	-0.01	0.19	0.19	-0.63

2.4.2 Azimuth Response

The method of azimuth response test is similar to the cosine response test. The output is measured at solar elevation angle 10° . The test point is at intervals of 30° within directional 60° ～300° . The cable of net pyrradiometer points to north which is 0° .

Table 2. The Relative Error for Azimuth Response（%）

No	Model	300°	270°	240°	210°	180°	150°	120°	90°	60°
007	DFY5	-7.63	1.78	0.63	5.65	-4.96	5.94	3.07	1.12	-5.60
008	DFY5	5.34	5.16	-14.52	5.30	2.41	1.26	-4.95	3.85	5.90
015	DFY5	8.81	10.98	0.71	3.72	-20.07	-4.10	0.74	1.32	-2.11
047	DFY5	1.96	4.32	2.56	3.87	-19.70	4.86	-0.08	4.01	2.42
9607	TBB-1	-1.25	0.34	-3.39	-2.03	-0.67	-1.08	5.85	6.53	4.31
9608	TBB-1	-10.43	2.97	11.42	10.92	2.74	-0.38	-5.45	-11.72	-10.50
9609	TBB-1	-2.52	2.40	-1.68	-4.32	1.94	1.11	-0.88	14.92	-10.97
9610	TBB-1	-9.21	-3.63	0.31	-0.85	4.08	6.91	1.99	2.21	-1.82

Azimuth response error is given by the formula $\delta_A=(V_Z/V_M-1)\times 100\%$. V_Z is the output of each azimuth and V_M is an average of outpoints for all azimuth. The results are given in the table 2. It shows that the error of azimuth response is in –20,07%～14.92%. According to the observation condition in use we should test 6 points, namely 60° , 90° , 120° , 240° , 270° , 300° and its error should be less than 15%. Pay attention to that the direction of net pyrradiometer must be the same whether in the test or in the observation, i.e. the cable of net pyrradiometer points to north.

2.5 Response Time

The response time is tested in both indoor and outdoor. The results are less than 90 second (99% response).

2.6 Influence of Dome-shape

The Influence of Dome-shape is tested on the laboratory test facility which the irradiance is adjusted to 500 W/㎡. According to the results maximum relative error of dome-shape is about 3%.

3.CONCLUSION

Based on our test study, we conclude that for net pyrradiometers of model DFY-5 and TBB-1, there are daytime sensitivity and night sensitivity which is within 5～16 $\mu V \cdot W^{-1} \cdot m^2$, nonlinearity error is less than 2.3%, temperature error is within ±5% in the range of -20℃～40℃, maximum cosine error is less than 16% and maximum azimuth error is less than 15% at solar elevation angle 10°, response time is less than 90 second (99% response) and maximum relative error of dome-shape is about 3%. Last, we want to stress that the cable of net pyrradiometer points to north and the polyethylene domes must be full of air in the observation in order to get a more accurate net radiation.

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