Report of the Working Group “Long-term Analysis of Surface SW Radiation Budget”

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Objectives

- Collection of various types of long-term surface SW radiation data and the related data including proxy-data useful for SW calculations.
- Comprehensive evaluation of the collected data.
- Promotion of the long-term analysis of surface SW radiation and the related data, focusing on their regional properties.

Workshop in Nanjing, China
22 May 2007

- 30 participants from China, Korea and Japan

- The QC procedures have no significant effect on the long-term trend of surface solar radiation over China.
- 1961 – 1990: Dimming, about 4.61%/10yr.
  - Aerosols? Clouds?
- 1990 – 2000: Brightening, about 1.76%/10yr.
  - What caused the brightening?
- 1961 – present: Temperature increasing
  - How can we understand the relation with SW radiation trend? - Evaporation process? Absorbing aerosols? Dynamics? Other climate system?

$$F_S^N + F_L^{\downarrow} = \varepsilon\sigma T_S^4 + H + LE + G$$

- SST might respond to SW radiation trend.

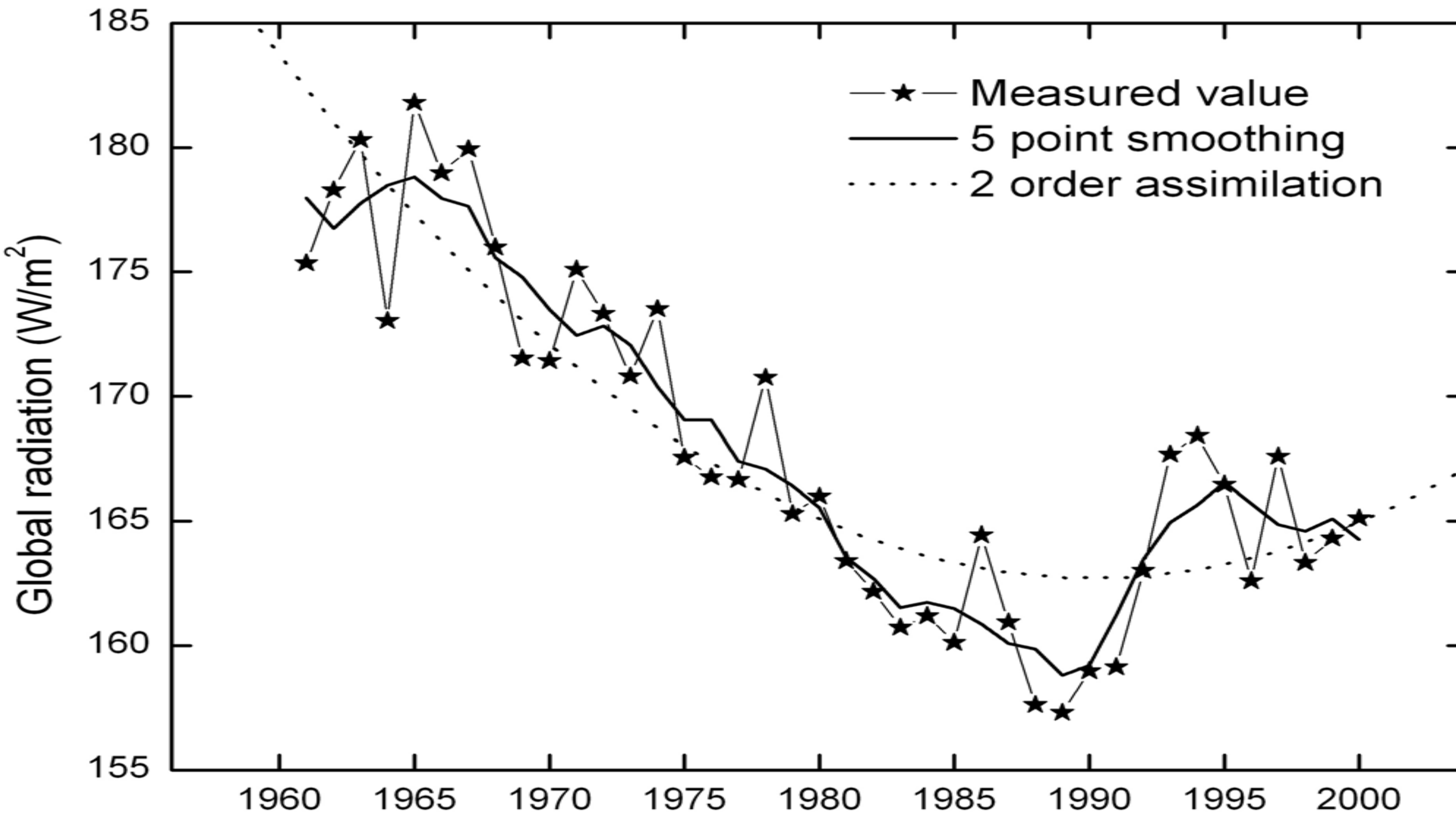
Methods of data quality assessment

- **QA1: Physical threshold test**
- **QA2: Sunshine duration test of global daily irradiation**
- **QA3: Standard deviation test for annually-averaged global irradiance time series (GEBA: Global Energy Balance Archive)**

(Shi et. al, 2008: JAMC, Vol. 47, pp.1006-1016)

Time series of annual mean of global irradiance at all stations

（Shi et al., 2008, JAMC）



Parameterizations for SW radiation

For clear sky condition, downward SW flux is estimated by using basic meteorological data,

$$\frac{S_{df}}{S_{0d}} = (C_1 + 0.7 \times 10^{-m_d F_1})(1 - i_3)(1 + j_1)$$

$$C_1 = 0.21 - 0.2\beta_{DUST}, \qquad \beta_{DUST} < 0.3$$

$$= 0.15, \qquad \beta_{DUST} \geq 0.3$$

$$F_1 = 0.056 + 0.16(\beta_{DUST})^{0.5}$$

$$i_3 = 0.014(m_d + 7 + 2\log_{10} w)\log_{10} w$$

$$j_1 = \left[0.066 + 0.34(\beta_{DUST})^{0.5}\right](ref - 0.15)$$

S_{df}: average downward SW flux on the Earth's surface,
S_{0d}: SW flux at the top of atmosphere,
β_{DUST}: turbidity factor, m_d: daily mean optical airmass,
w: precipitable water, ref: surface albedo

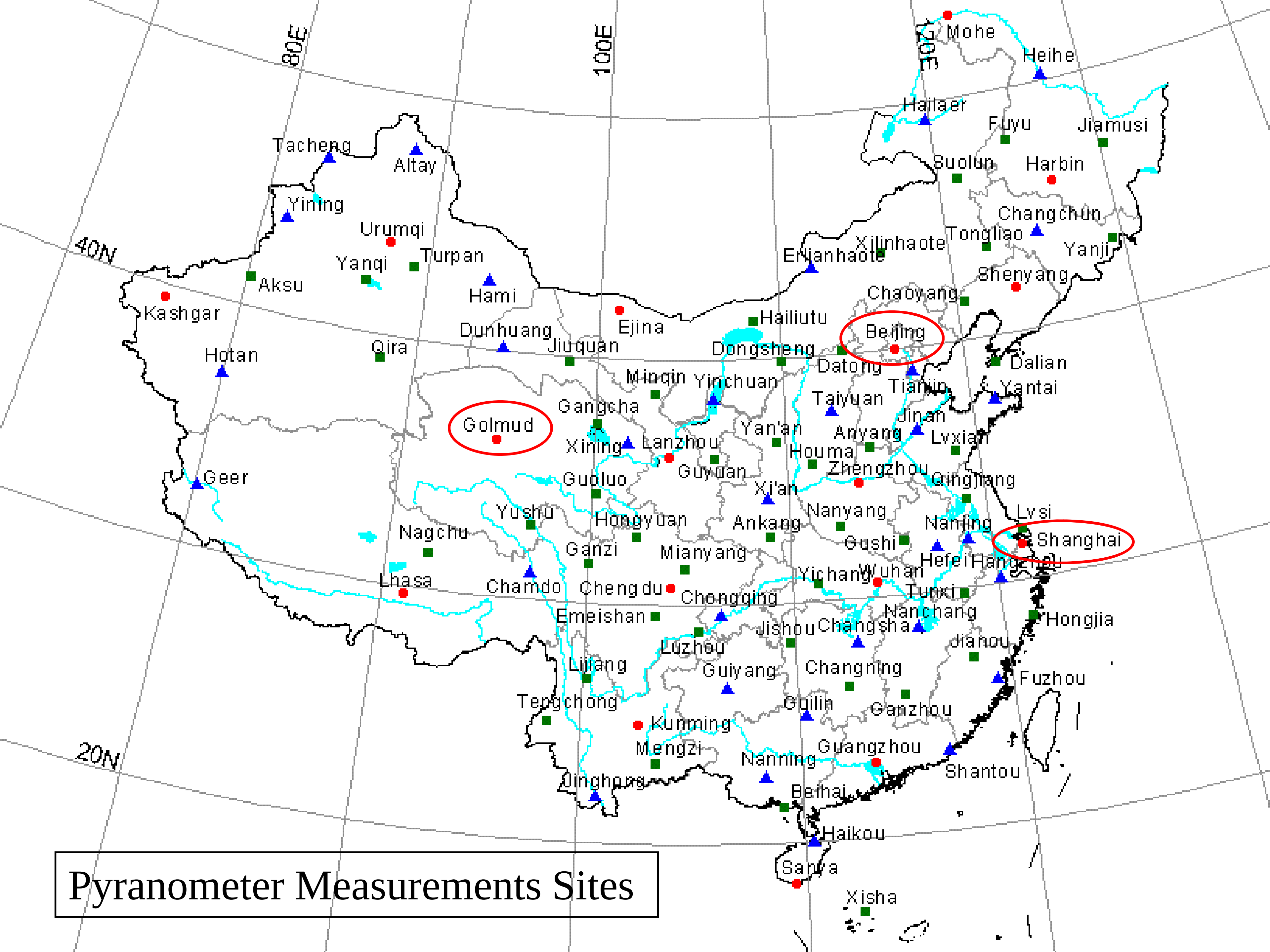
Parameterizations for SW radiation (2)

For cloudy sky condition, downward SW flux is estimated from sunshine duration,

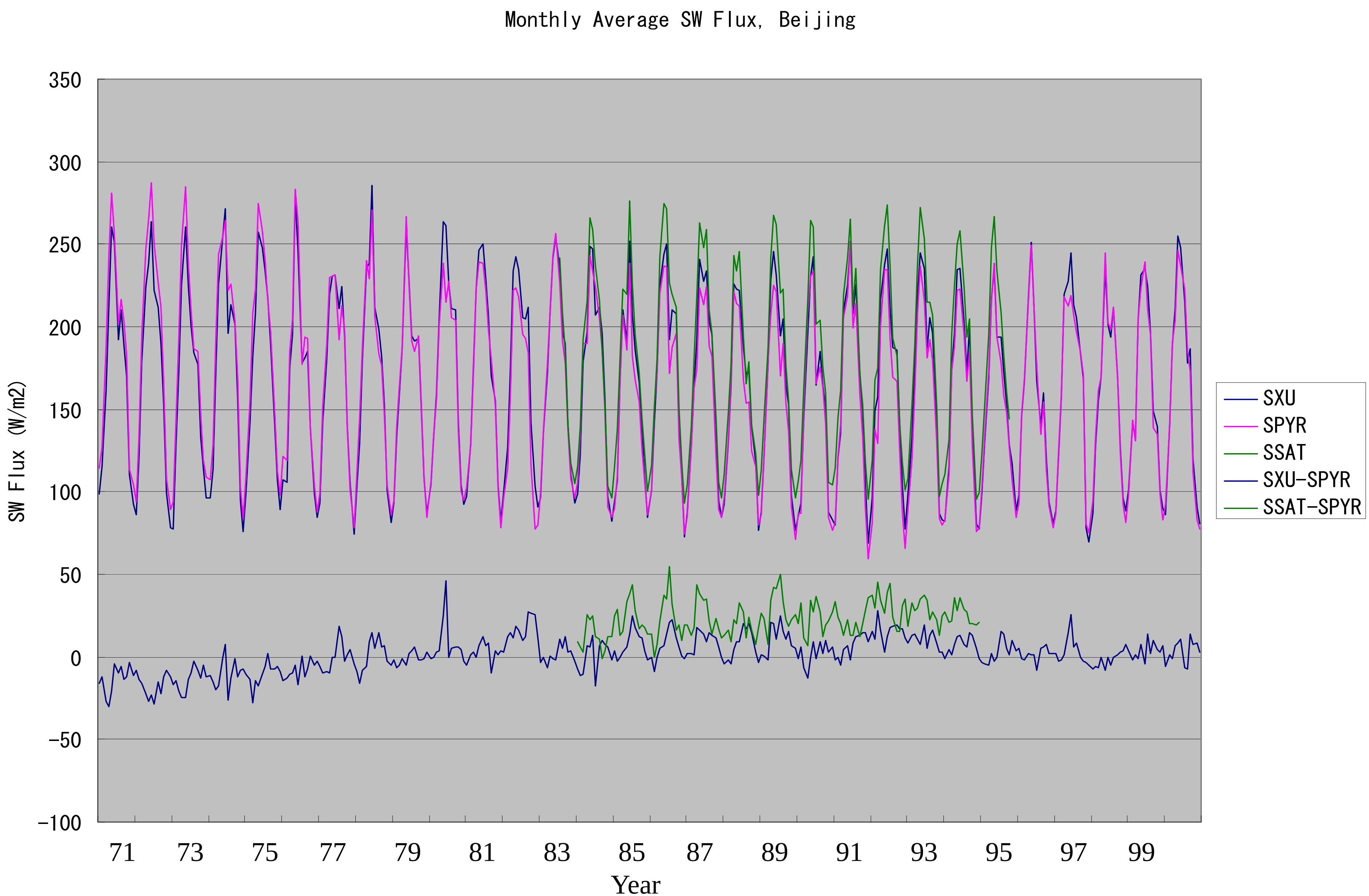
$$\frac{S_d}{S_{0d}} = a + b\frac{N + \Delta N}{N_0} \quad \text{for} \quad 0 < \frac{N}{N_0} \le 1$$

$$= c \quad \text{for} \quad \frac{N}{N_0} = 0$$

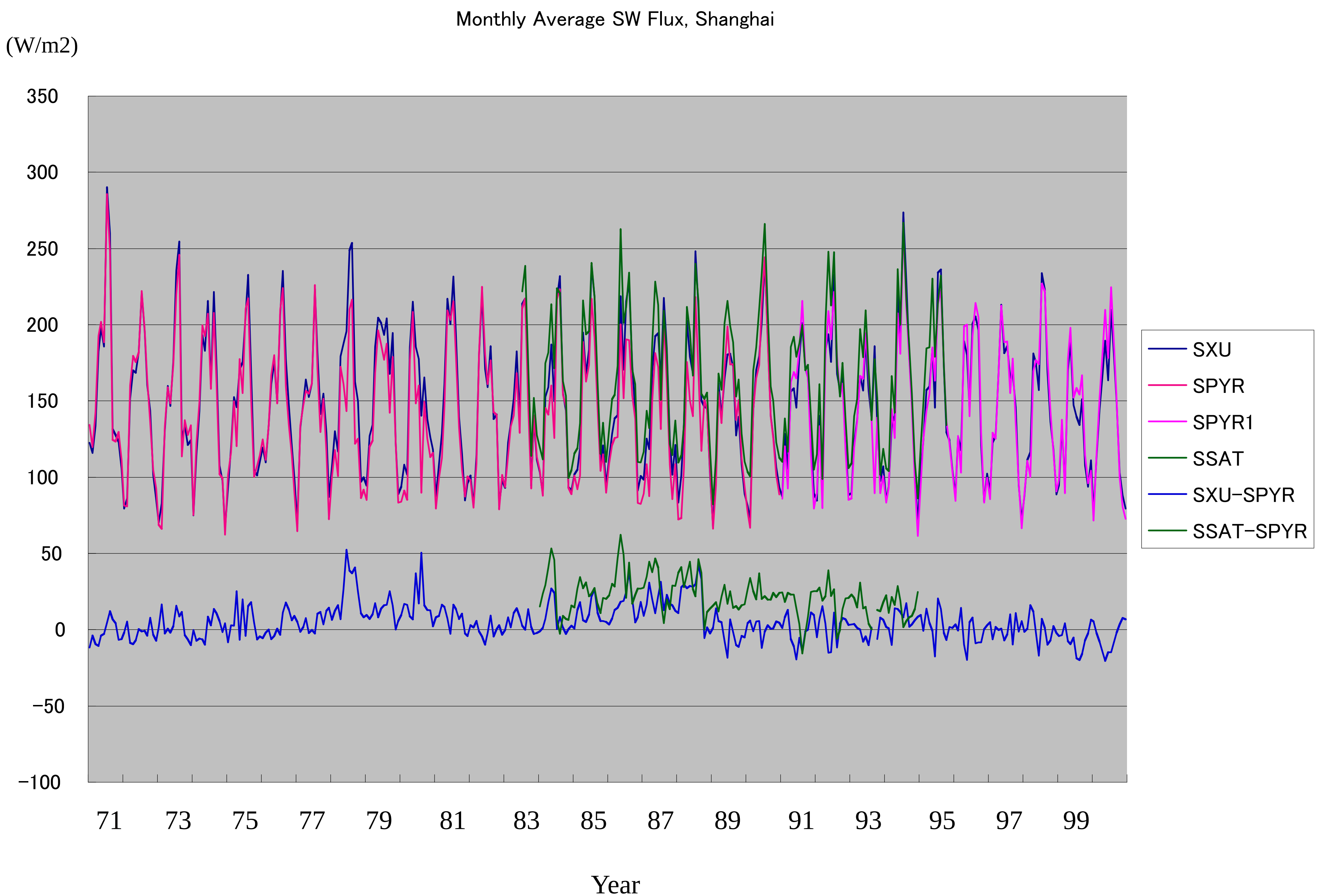
S_d: average downward SW flux on the Earth's surface,
S_{0d}: SW flux at the top of atmosphere,
N: sunshine duration, N_0: maximum sunshine duration,
a, b, c, ΔN: parameters depending on the instrument type



Pyranometer Measurements Sites



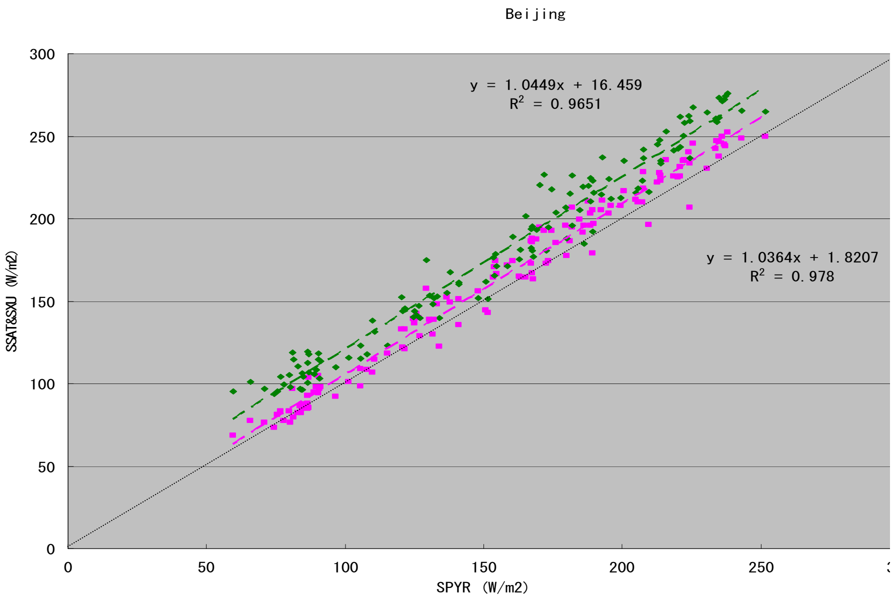
Monthly Average SW Flux, Beijing
350
300
250
200
150
100
50
0
-50
-100
SW Flux (W/m2)
71
73
75
77
79
81
83
85
87
89
91
93
95
97
99
Year
SXU
SPYR
SSAT
SXU-SPYR
SSAT-SPYR

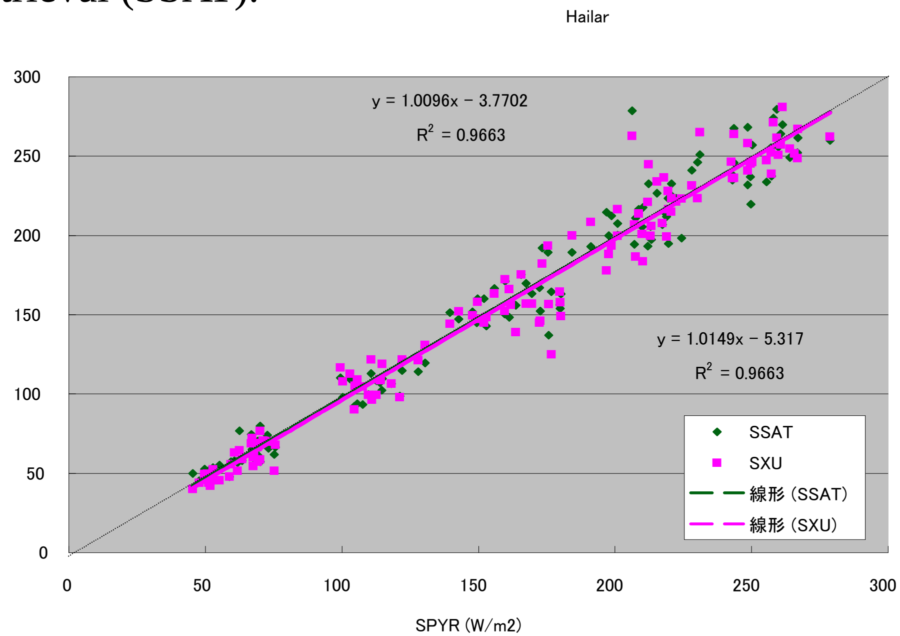


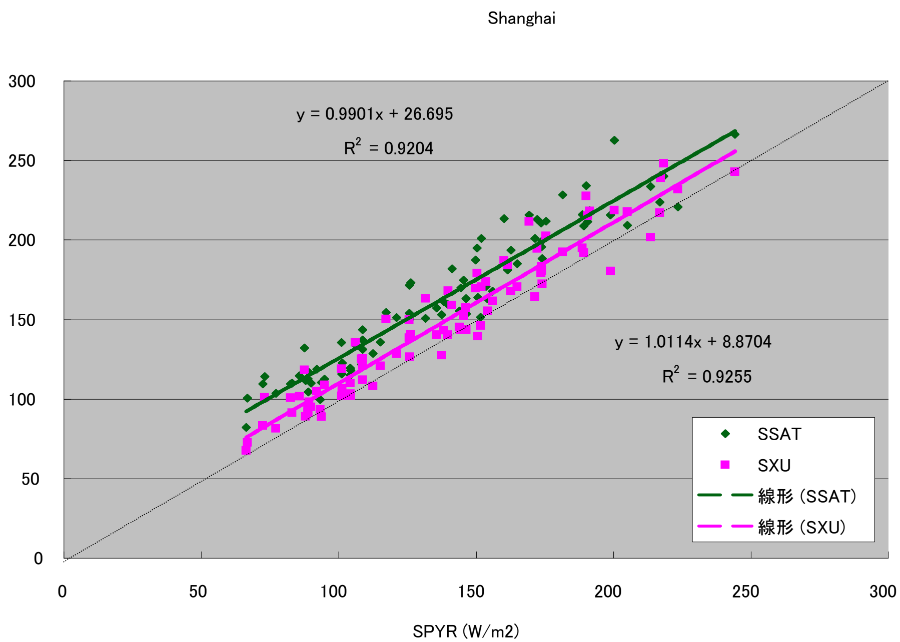
Monthly Average SW Flux, Shanghai
(W/m2)
350
300
250
200
150
100
50
0
−50
−100
71
73
75
77
79
81
83
85
87
89
91
93
95
97
99
Year
SXU
SPYR
SPYR1
SSAT
SXU−SPYR
SSAT−SPYR

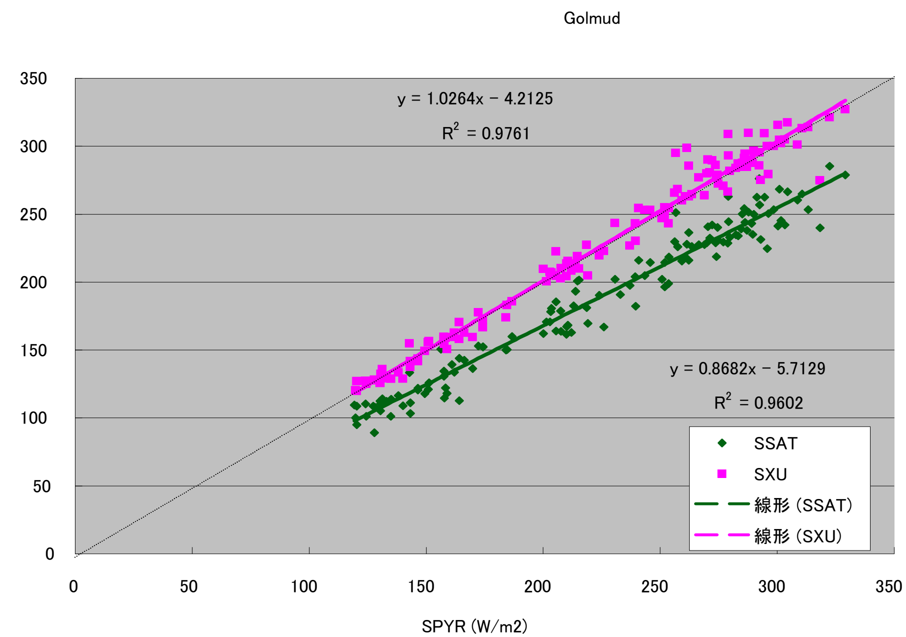
Monthly Average SW Flux, Golmud
(W/m2)
350
300
250
200
150
100
50
0
−50
−100
71
73
75
77
79
81
83
85
87
89
91
93
95
97
99
Year
SXU
SSAT
SPYR
SXU−SPYR
SSAT−SPYR

Comparison of SW radiation among the pyranometer measurement (SPYR), the parameterization (SXU), and the satellite retrieval (SSAT).









Future work

- Collection and archive of radiation data
- Comparison of QA (BSRN, GEBA, satellite data, etc.)
- Assessment of radiation data with related data (clouds, aerosols, etc.)
- Promotion of the long-term analysis of surface SW radiation and the related data.
- Website, workshop or meeting

30 June 2006

Report of the WMO Ad-Hoc Group Meeting
on
Programmatic Gaps Related to the Global Radiation Network Served by the World Radiation Data Centre, MGO, Russia

7-8 June 2006 St. Petersburg Russia

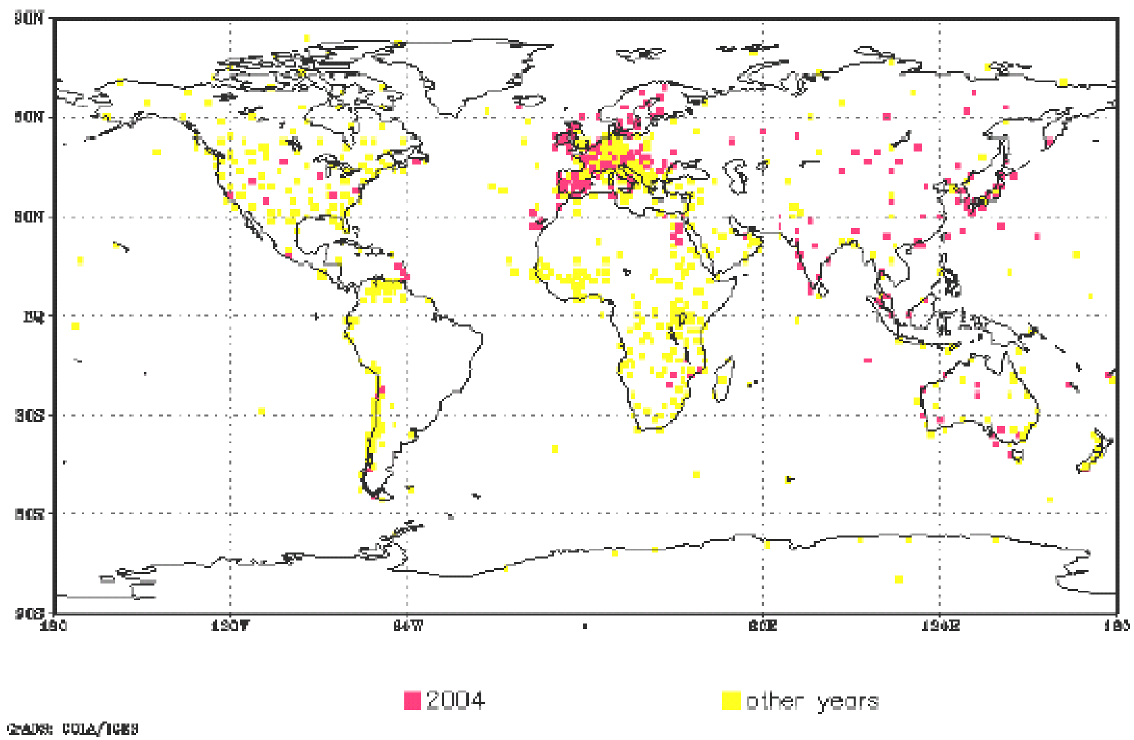


Figure 1 The red points indicate the number of stations in the Global Surface Radiation Network (GSRN) reporting data in 2004 to the WMO-GAW World Data Centre for Radiation. The fainter yellow points represent all other locations that, at some time between 1964 and 2004 , have submitted data (courtesy of A. Tsvetkov, head of WRDC)

QA1: Physical threshold test

- Global radiation, G
  - Upper limit: The daily solar global radiation in clear sky condition.
  - Lower limit: According to the research of Geiger et al. [2002], the lower limit here is set as 3% of solar radiation at TOA.
- Diffuse radiation, D
  - Upper limit: The daily solar global radiation in clear sky condition.
  - Lower limit: The daily surface diffuse radiation under clear sky condition.
- Direct radiation, B
  - Upper limit: The daily surface direct solar radiation under clear sky condition.
  - Lower limit: Zero.

QA2: Sunshine duration test of global radiation

- The monthly percentage of sunshine duration (MPSD) of each station is calculated according to monthly sunshine duration data. The MPSD is the ratio of monthly observed sunshine duration S to the monthly available sunshine duration L.
- To compare sunshine duration percentage with surface global radiation, we need to calculate a ‘clearness index, *K* ’, from radiation data. Monthly averaged *K* is calculated by $K = G/G_0$, where G_0 is the incident irradiance at TOA

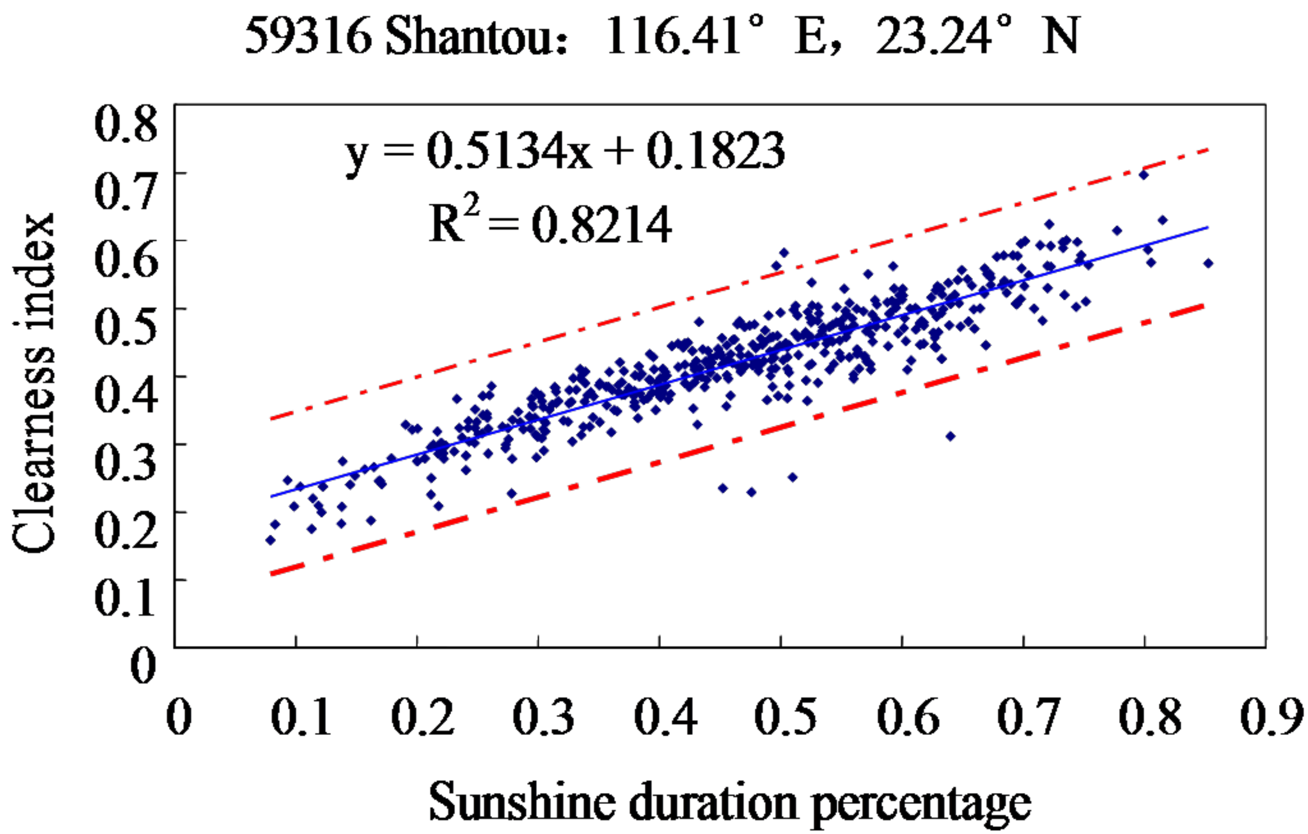


Figure 4 scatter plots of sunshine duration percentage and clearness index

As the result of QA2 test, the ESD is different from the site to site and its range varies from 0 to 2.35%. The geographic distribution of the ESD is relatively uniform and among all of 27196 monthly data tested, 210 did not pass through QA2 tests, which is about 0.77%.

QA3: Standard deviation test of time series for annual averaged global radiation

- For the time series of the annual averaged values Y of solar global radiation, *Y(t)*, its average m_Y, and standard deviation S_y can be calculated by

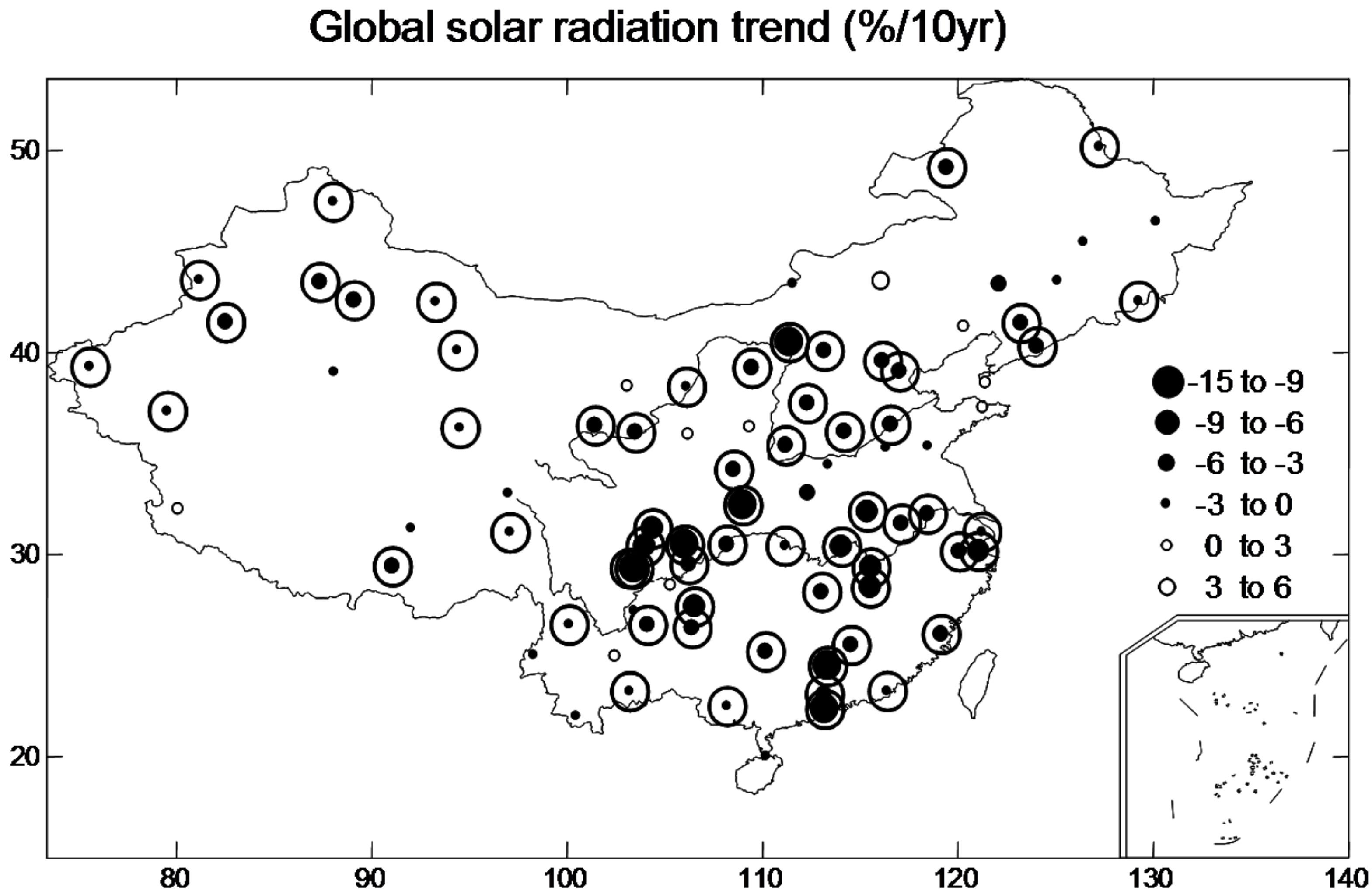
$$m_Y = \frac{1}{N} \sum_t Y(t) \quad ,$$

and

$$s_Y^2 = \frac{1}{N-1} \sum_t [Y(t) - m_Y]^2 \quad ,$$

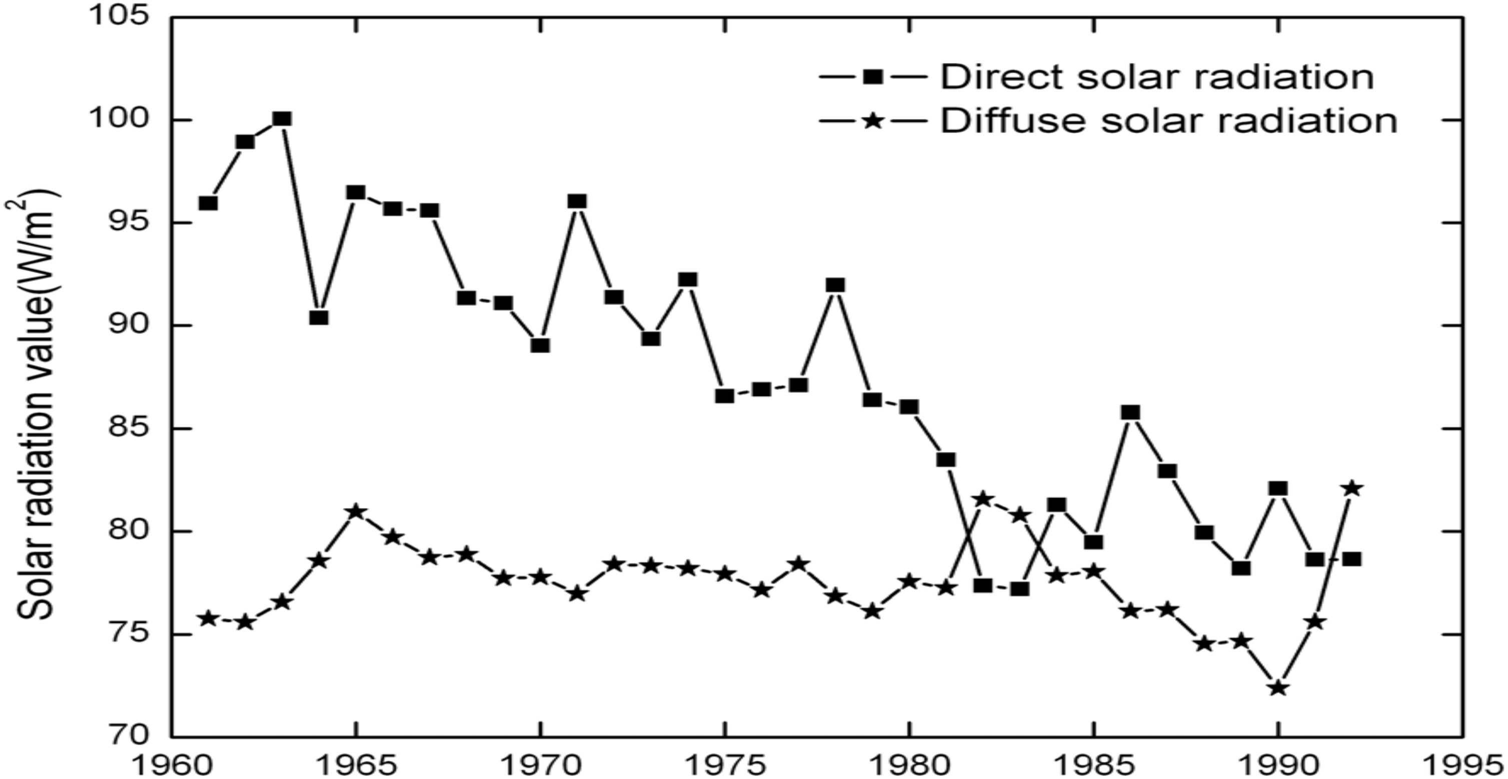
where *N* is the observation period with a unit of year.

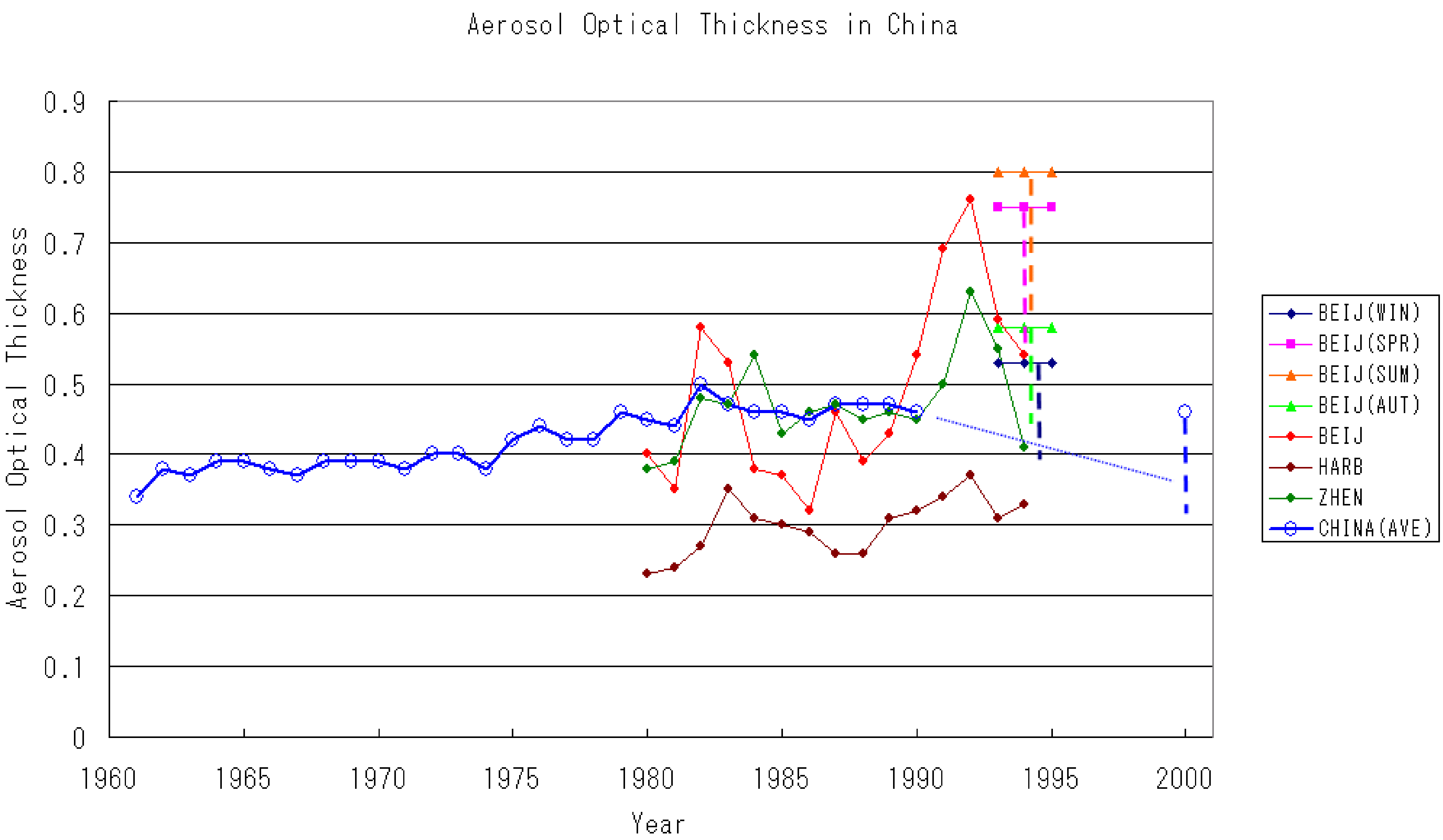
1961-2000



Global solar radiation trend (%/10yr)
50
40
30
20
80
90
100
110
120
130
140
-15 to -9
-9 to -6
-6 to -3
-3 to 0
0 to 3
3 to 6

Long-term variations of annual mean of direct and diffuse irradiance.





From Qiu et al. (2000), Luo et al. (2001), Chu et al. (2003)

Results of QA1

Table 1 Test thresholds and results of three variables

Variable	Lower limit	Upper limit	Measurement Days	Error days	Percent of error days
G	$0.03G_0$	*G*c	1220107	37466	3.07
B	0	*B*c	813929	117	0.01
D	*D*c	*G*c	813943	20479	2.52
Total			2847979	58062	2.04

Table 2 Monthly distributions of error days

Variables	Error days（upper limit error days /lower limit error days）											
	1	2	3	4	5	6	7	8	9	10	11	12
G	885/ 3542	566/ 3636	424/ 3549	255/ 2466	263/ 2208	176/ 2253	167/ 1781	168/ 1613	239/ 2511	380/ 3087	564/ 2945	816/ 2937
D	0/ 2489	0/ 2521	0/ 2191	0/ 1487	0/ 1221	0/ 1185	0/ 884	0/ 865	0/ 1503	0/ 1985	0/ 2014	0/ 2134
B	26/0	8/0	8/0	12/0	2/0	0/0	2/0	1/0	9/0	16/0	19/0	14/0

Table 3 Regional averages of global solar radiation $m(m_Y, Z)$ and standard deviation $m(s_Y, Z)$ and $s(s_Y, Z)$

Region	$m(m_Y, Z)$	$m(s_Y, Z)$	$s(s_Y, Z)$
50°-60°N	119	6.4	1.14
40°-50°N	154	9.38	4.45
30°-40°N	196	12.27	3.94
20°-30°N	213	10.00	2.75

GEBA: $m(sY, Z) + 2s(sY, Z)$ is used.

Among 3068 year-station data tested by QC3, 15 have been identified to be the ESD which is about 0.49% of the total.

ISCCP-FD - Pyranometer data

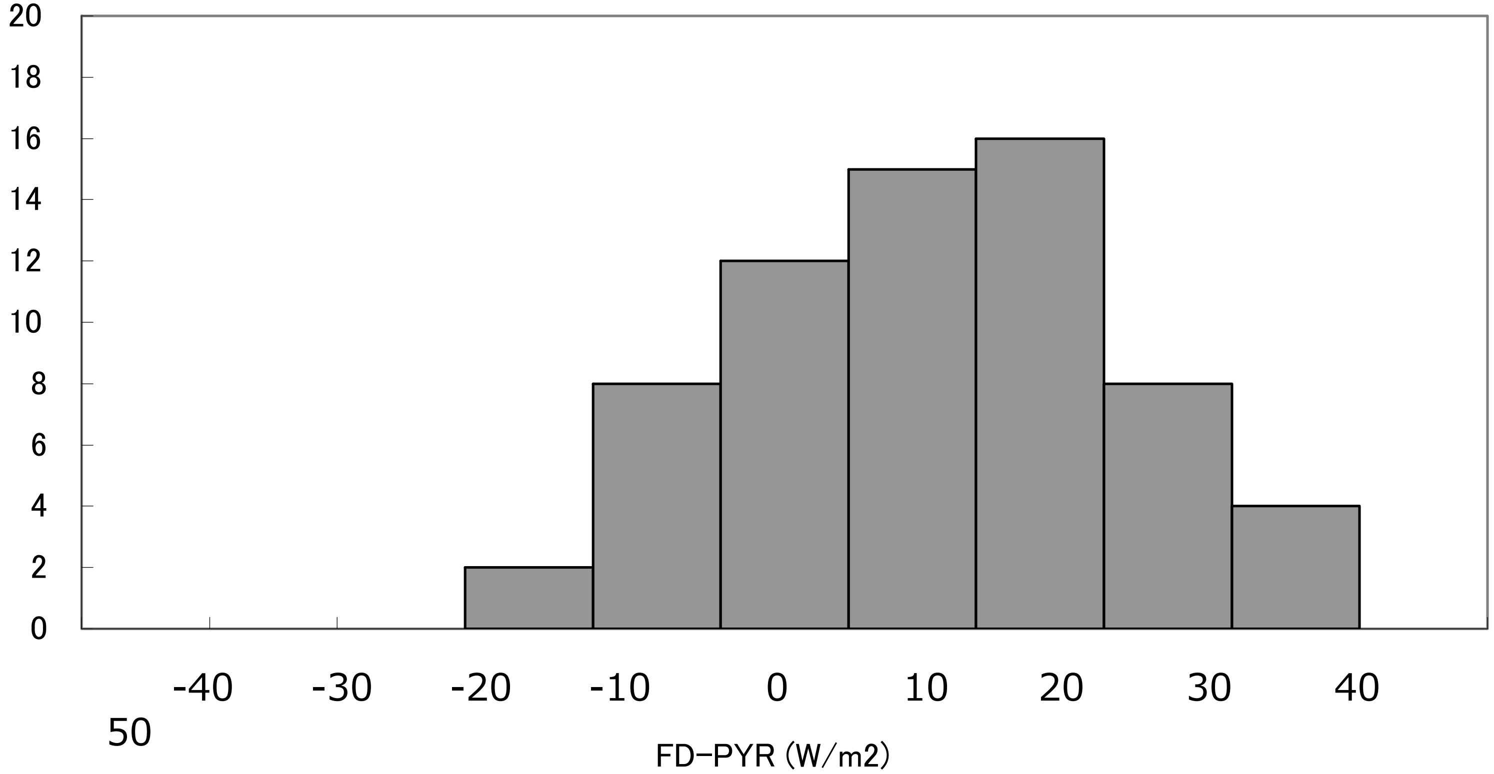


Fig. 3

GEWEX-SRB - Pyranometer data

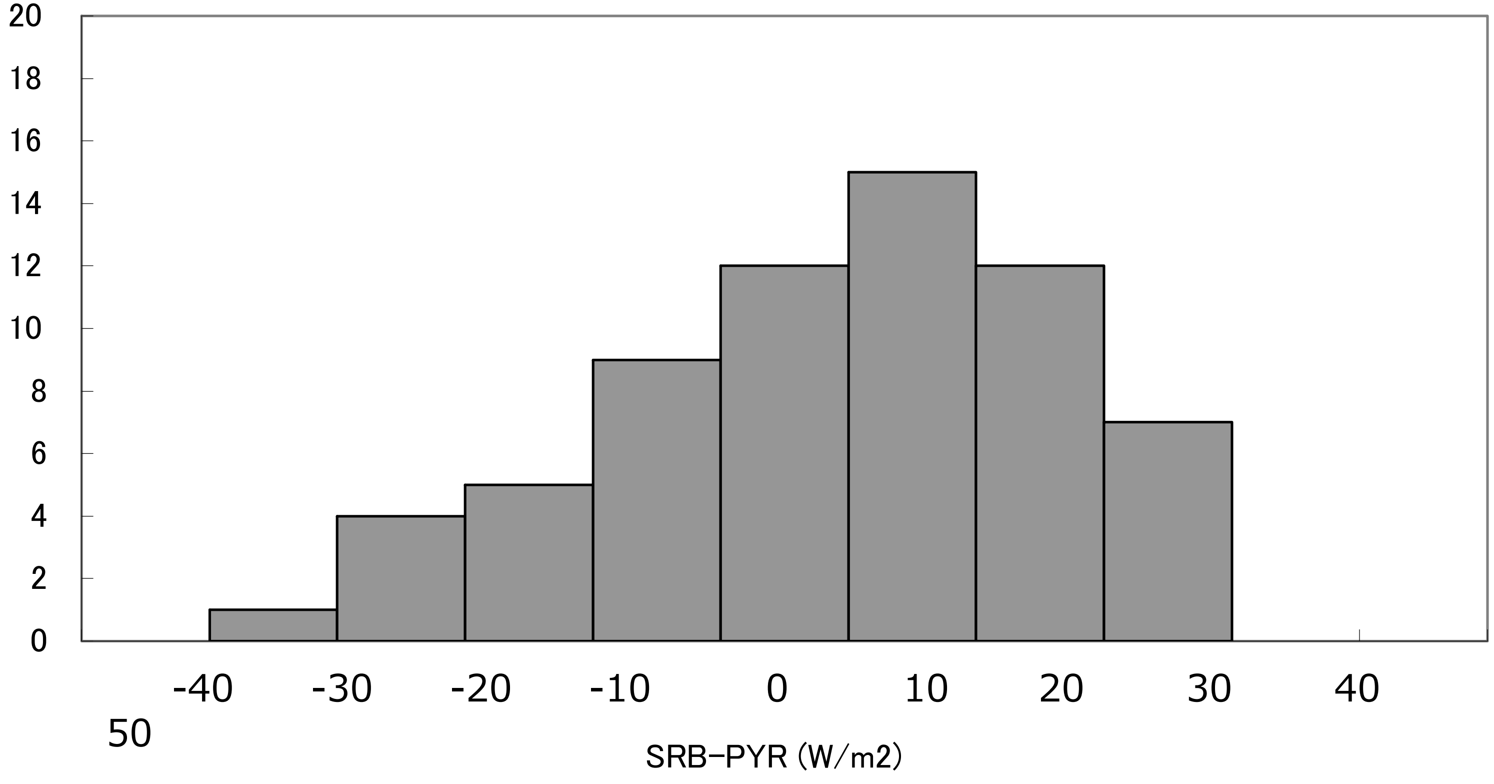


Fig. 2