RIC-Tsukuba (Japan) Intercomparison of Thermometer Screens/Shields in 2009 – 2010

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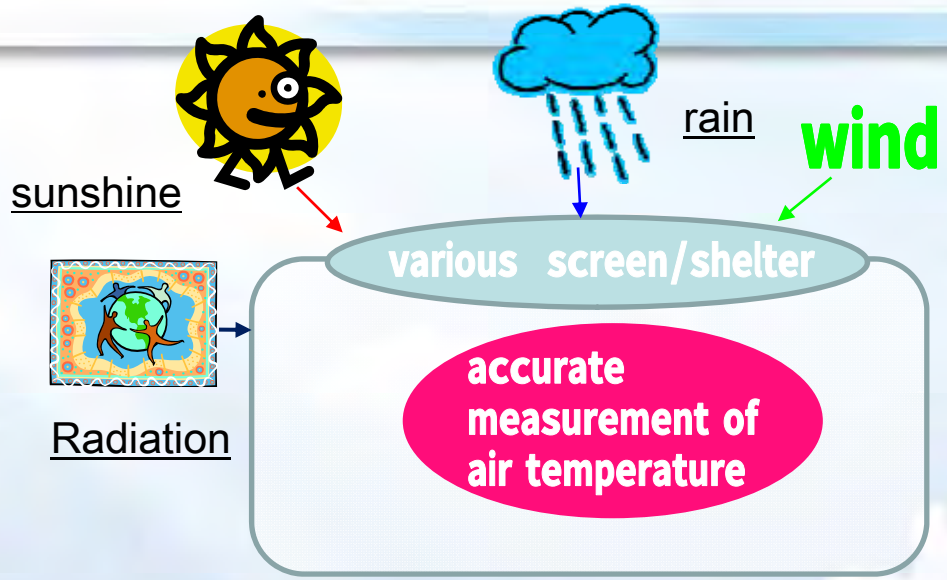
RIC-Tsukuba, Japan Meteorological Agency (JMA)

29 July, 2010

1. Introduction



●To aid accurate measurement of air temperature, various screens/ shields have been designed and used to protect thermometers from sunshine, radiation, rain and wind and so on.

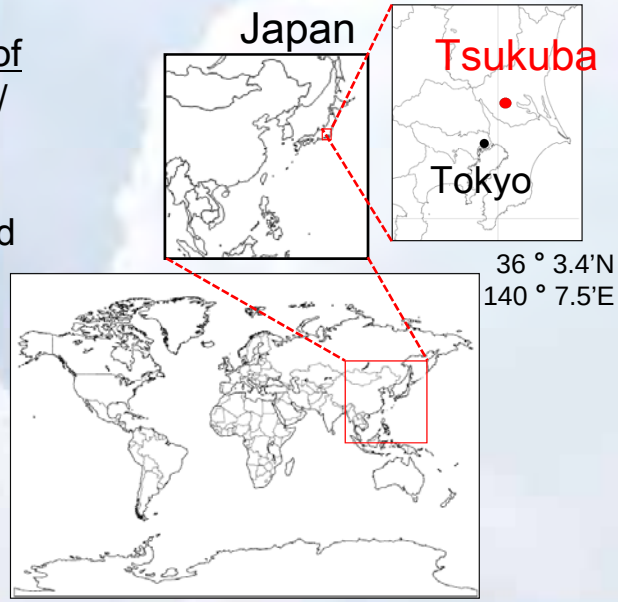
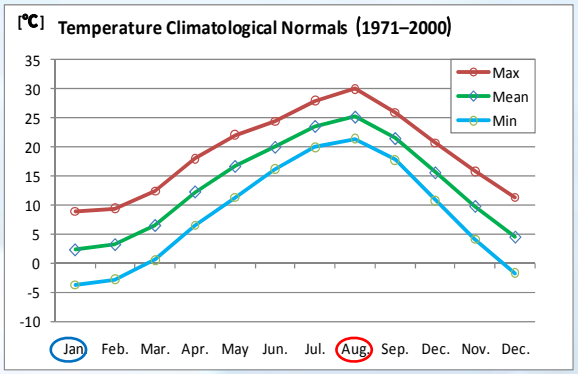
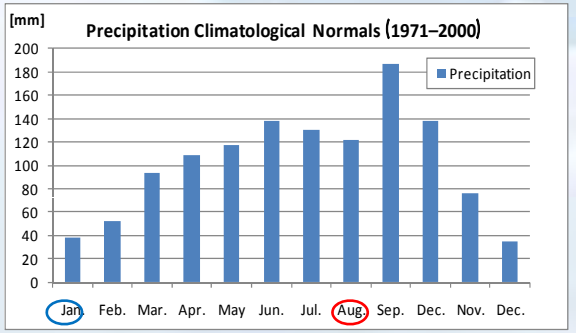


Fig. 1 Location of Tsukuba

Fig. 2 Climatological normals for Tsukuba (upper: monthly temperature; lower: precipitation)

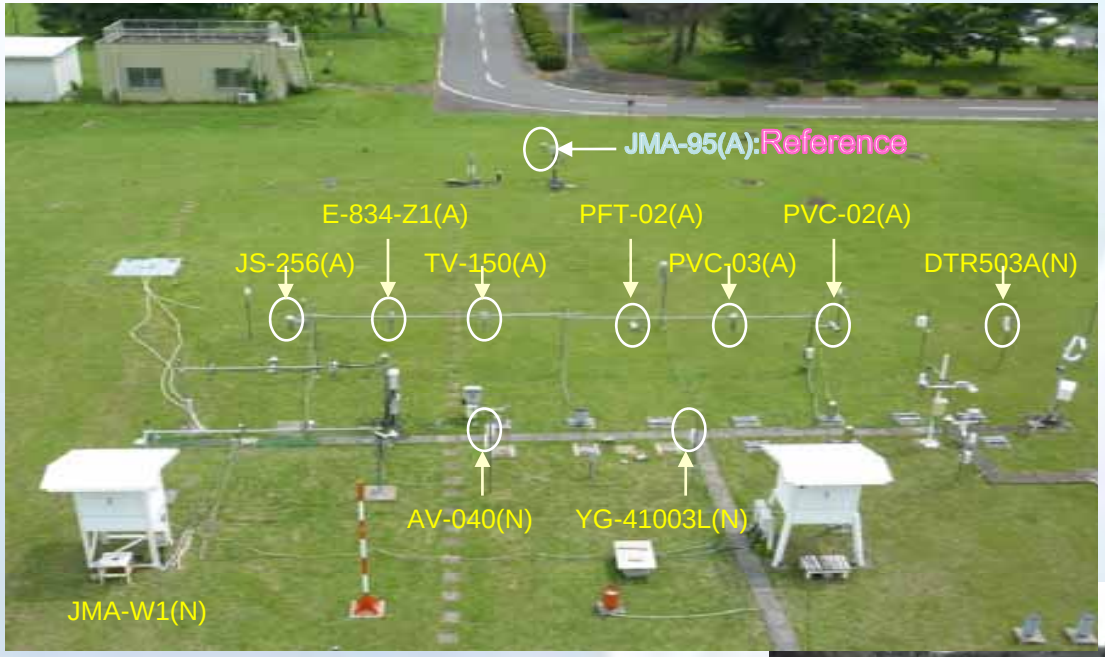




・ Tsukuba has a temperate rainy climate and high temperatures in summer (Cfa) according to the Köppen-Geiger climate classification.

2. Intercomparison Overview
2.1 Type of screens/shields tested and sensors

Photo. 1 Location of screens/shields in the intercomparison field (north – south side view)



・ Reference is JMA-95(A), the screen/shield is used on operational surface observation.

・ This experiment was carried out in summer season, and in winter and spring season.

・ unified platinum resistence thermometer Pt 100Ω (the size is 3mm in diameter) because we wanted to evaluate only screens effect.

Intercomparison field (west – east side view)

2.1 Type of screens/shields tested and sensors

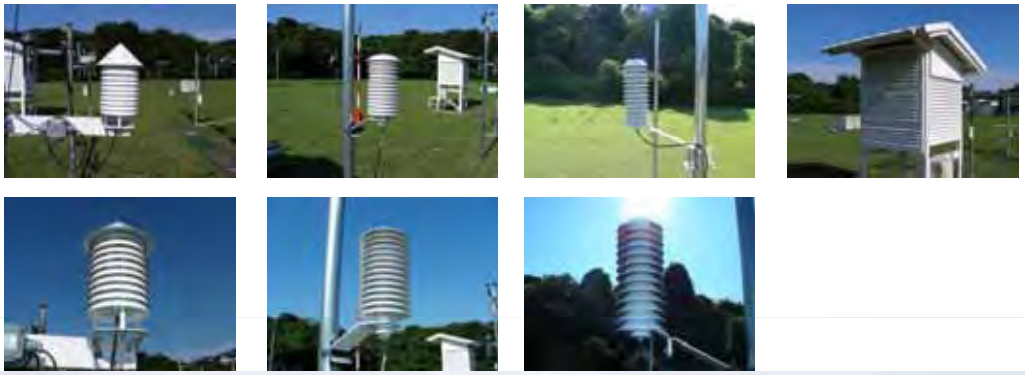
Photo. 2 Pictures of screens/shields (upper: side view; lower: view from underneath)

Artificially ventilated screens/shields

JMA-95(A) JS-256(A) E-834-Z1(A) TV-150(A) PVC-03(A) PVC-02(A) PFT-02(A)

Naturally ventilated screens/shields

AV-040(N) YG-41003L(N) DTR503A(N) JMA-W1(N)



upper: side view

lower: view from underneath

3. Results

3.1 Statistical values

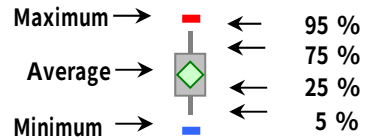
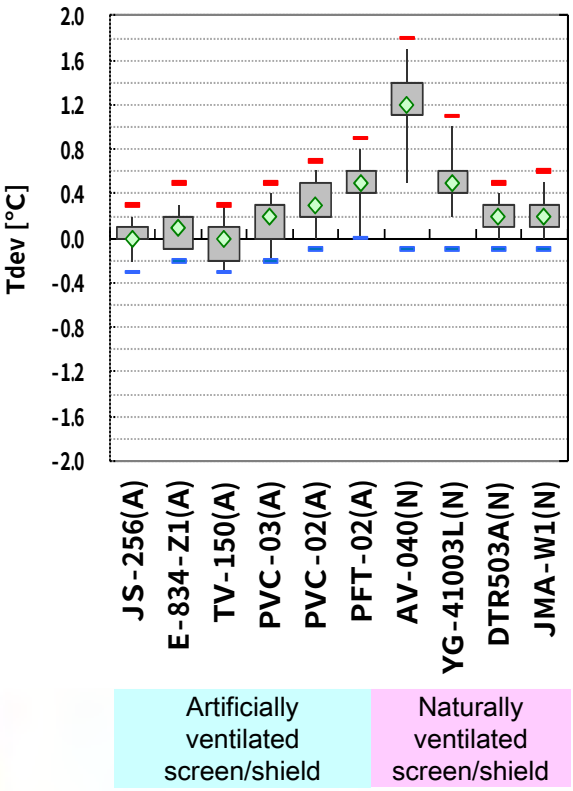


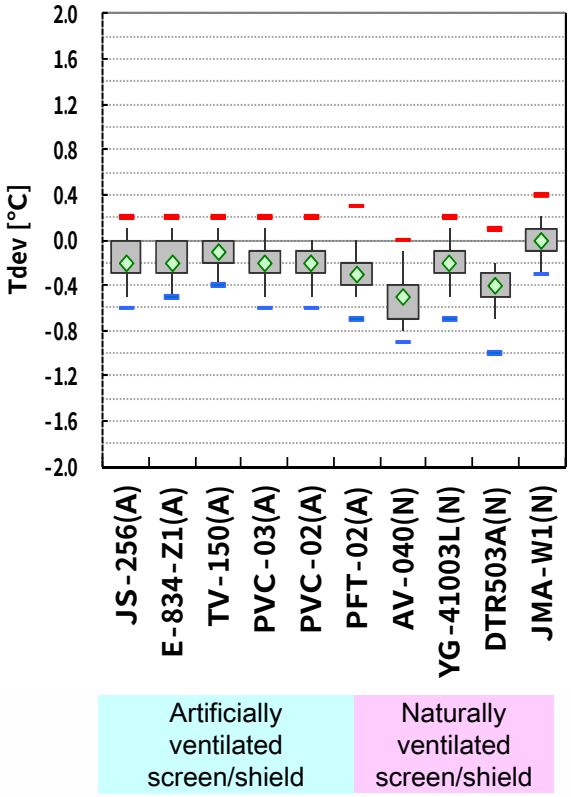
Fig. 3 Tdev (temperature deviation) of daily temperature (reference: JMA-95(A))

Capitalize first letter of “Maximum/Average/Minimum” (same rule below for all graph legends).

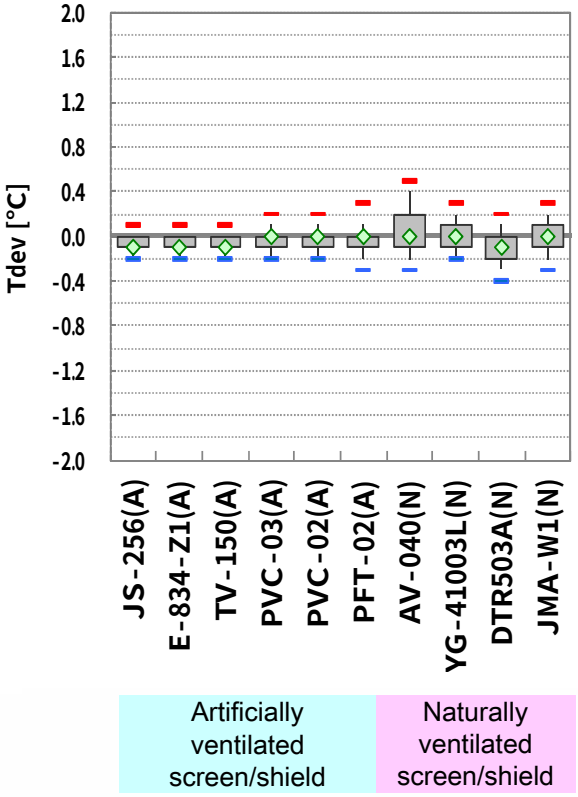
(a) maximum temperature
Aug. 2009 (summer)



(b) minimum temperature
Jan. 2010 (winter)



(c) average temperature 6months
(Aug., Dec., Jan., Feb., Mar. and Apr.)

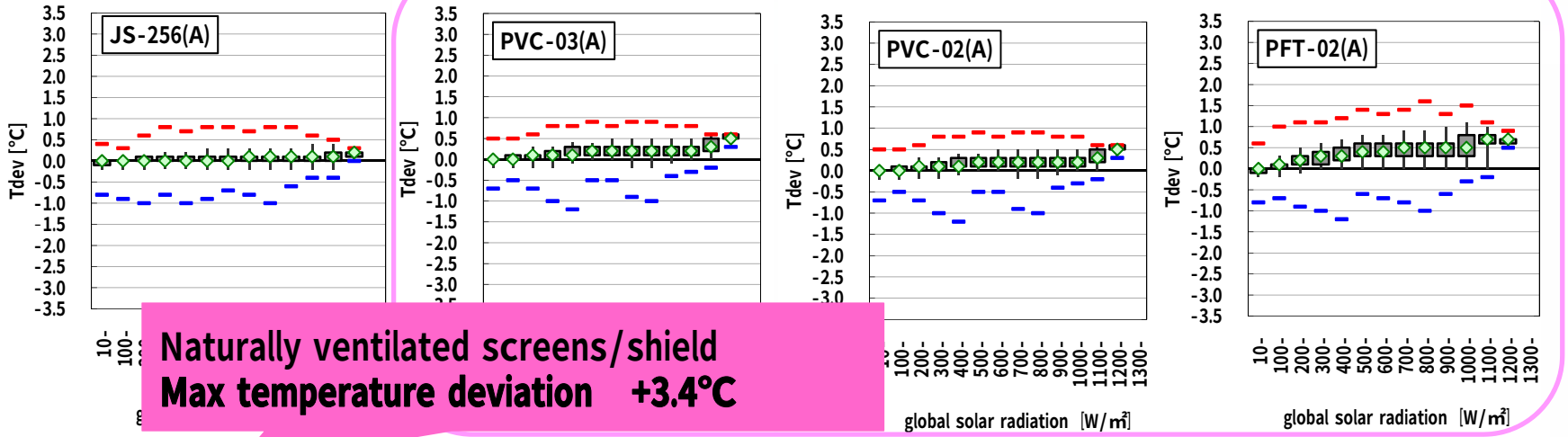


3.2 Influences of global solar radiation

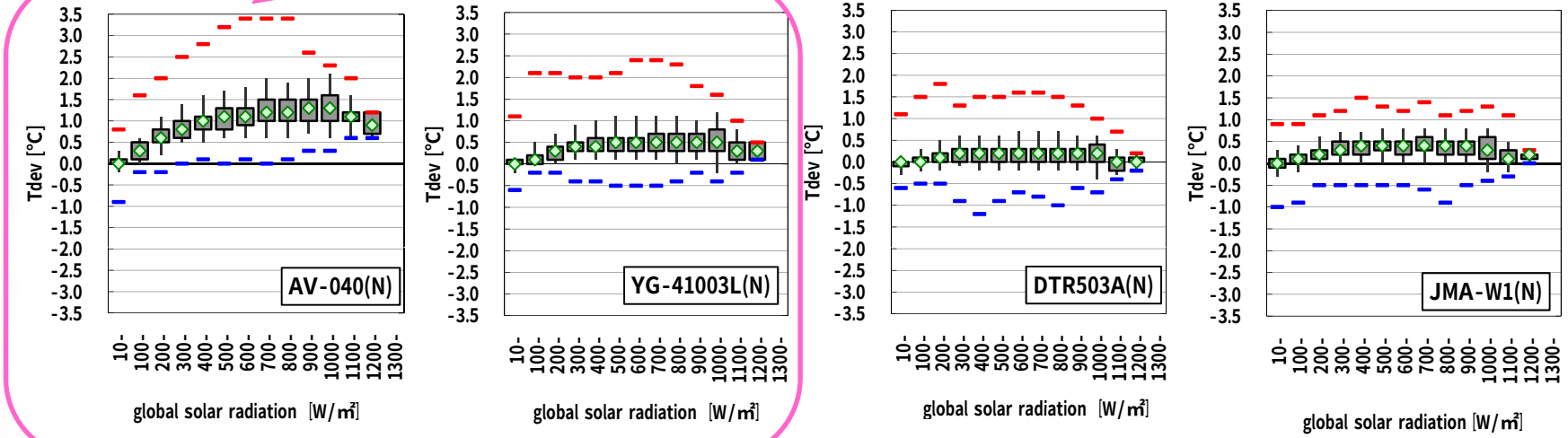
Maximum → ← 95 %
Average → ← 75 %
← 25 %
Minimum → ← 5 %

Fig. 4 Tdev differences related to g /shield, Aug. 2009

Artificially ventilated screens/shield
but no insulator → positive influences



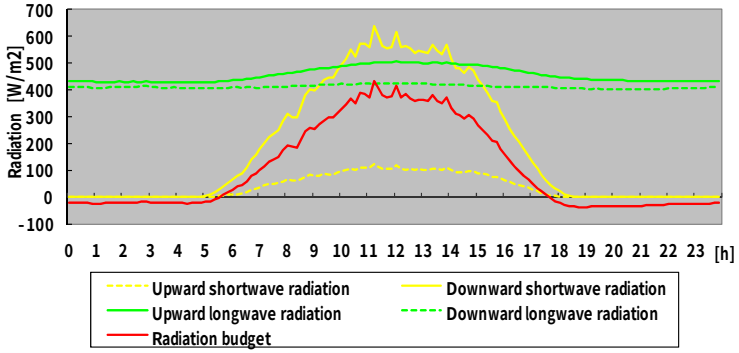
Naturally ventilated screens/shield
Max temperature deviation +3.4°C



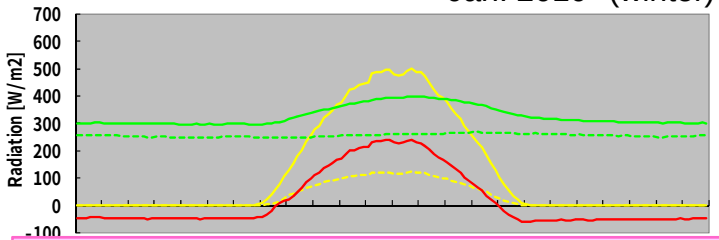
3.3 Influences of radiation budget

Fig. 6 Time series representations of monthly mean Tdev and radiation budget

I (a) Radiation budget Aug. 2009 (summer)

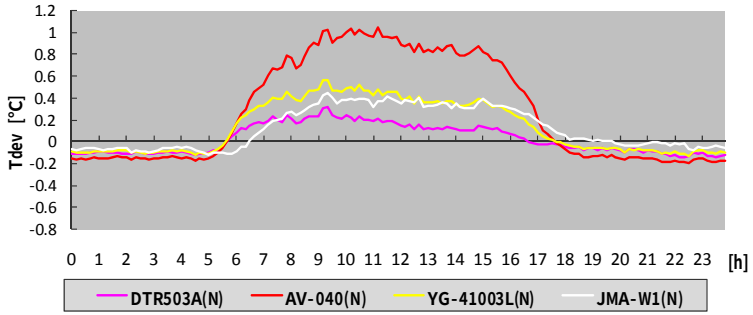


II (a) Radiation budget Jan. 2010 (winter)

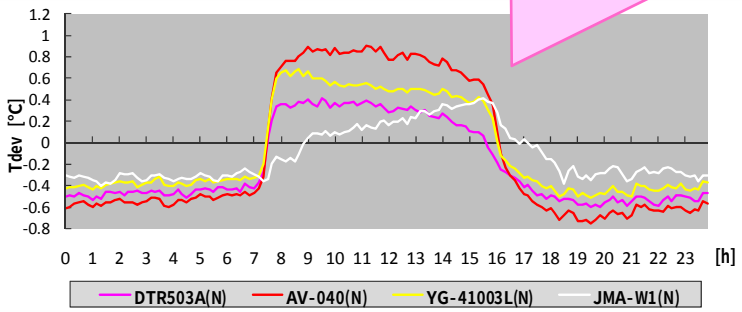


・Largest negative Tdev → AV-040(N)
・around sunrise and sunset Tdev changes remarkably

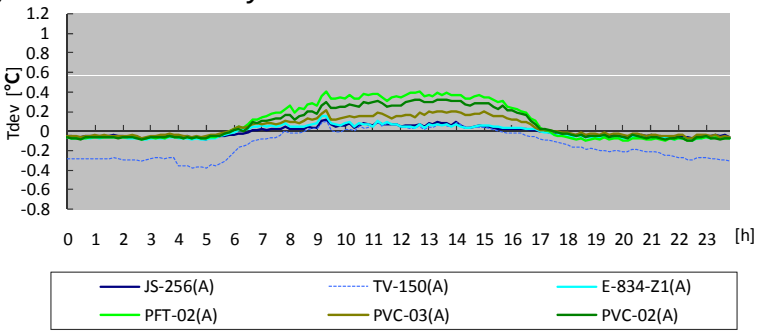
(b) Tdev of naturally ventilated screens/shields



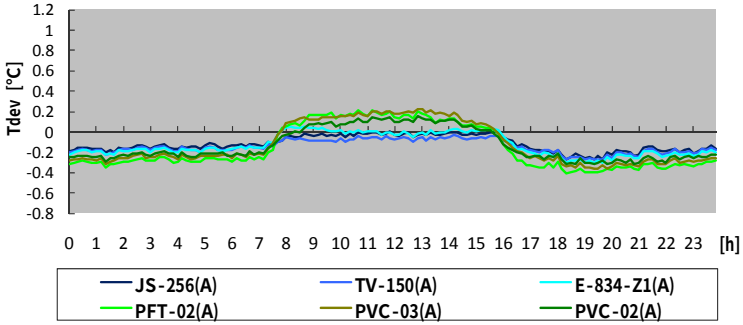
(b) Tdev of naturally ventilated sc ds



(c) Tdev of artificially ventilated screens/shields



(c) Tdev of artificially ventilated screens/shields



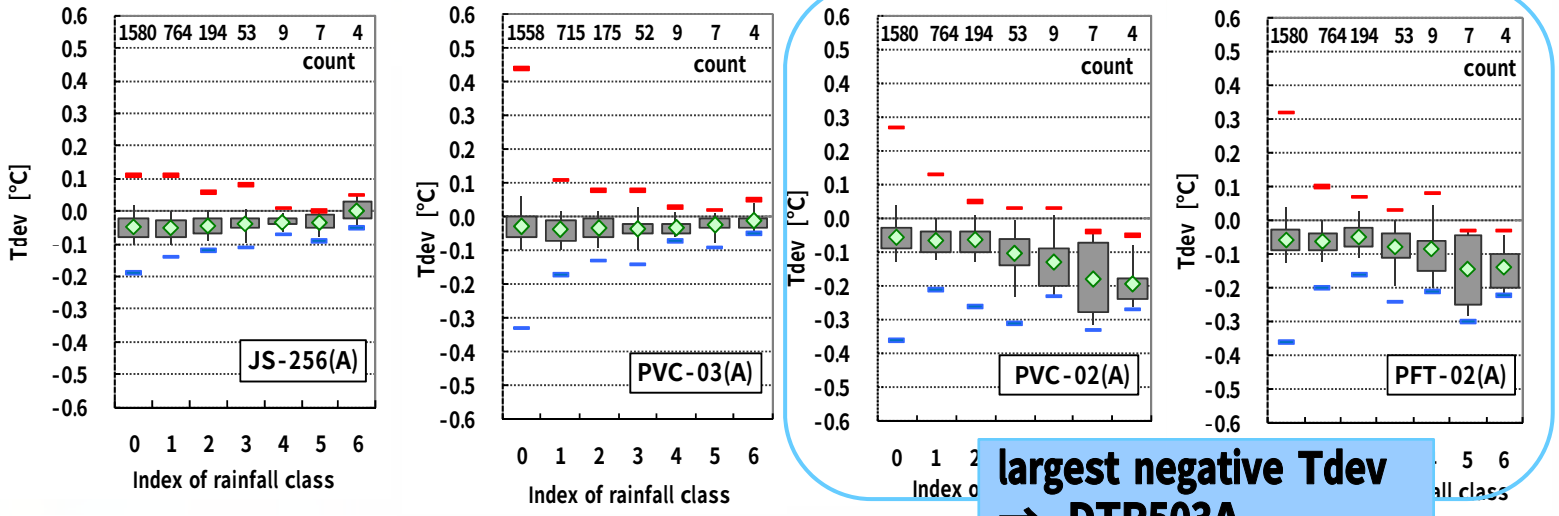
Reference: JMA-95(A). The dotted line in (c) includes missing data over periods of two days or more.

3.4 Influences of rainfall

Maximum → ← 95 %
Average → ← 75 %
Minimum → ← 25 %

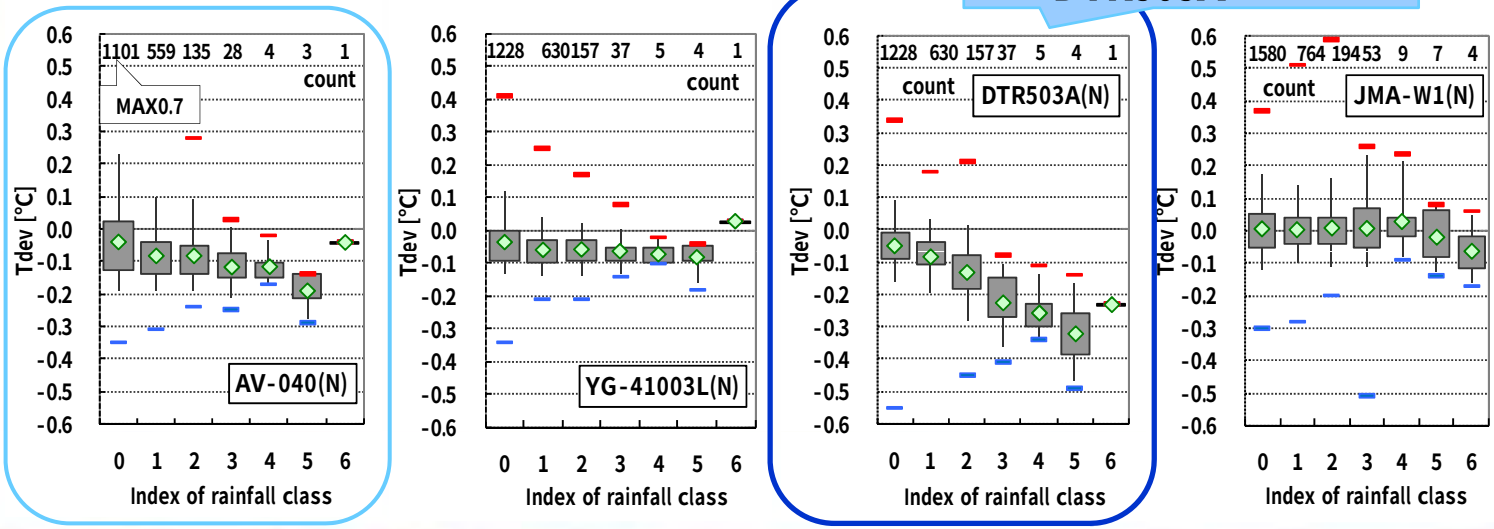
Fig. 7 Tdev differences related to rainfall intensity depending on each screen/shield

for 31 days when the total rainfall was 10 mm per day or more



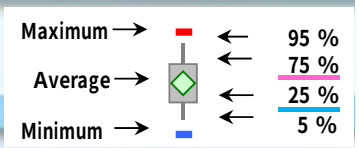
Index of rainfall class	Rainfall per 10 min. [mm/10min.]
0	>0.5
1	0.5
2	1～1.5
3	2～3
4	3.5～4.5
5	5～6.5
6	7≦

largest negative Tdev → DTR503A



3.5 Comprehensive evaluation 1/3

Table 1 Characteristics and variation of Tdev related to various meteorological factors for each screen/shield



Ventilation		Artificially							Natural			
Type		JMA-95 (A) (JS-258)	JS-256 (A)	E-834-Z (A)	TV-150 (A)	PVC-03 (A)	PVC-02 (A)	PFT-02 (A)	AV-040 (N)	YG-41003L (N)	DTR503A (N)	JMA-W1 (N)
Manufacturer		Ogasawara	Ogasawara	Yokogawa	Ogasawara	Prede	Prede	Prede	Ogasawara	R. M. Young	Vaisala	Hidakosya
Structure of screen	Form	Vertical type					Horizontal type (pole)	Horizontal type (roof)	10 plates (flat) +snow umbrella	14 plates (dish upside down) inner: curved downward	12 plates (dish) rim: flat	Roof, blinds, base: duplication
	Inside structure	Duplication tube							–			
	Insulator/underneath shield plate	○				–			–			
	Material	Stainless steel (SUS304)	Stainless steel (SUS304) Aluminium	Stainless steel (SUS314)	Stainless steel (SUS304)	Stainless steel (SUS304) Portion: aluminium	Stainless steel (SUS304)	Stainless steel (Portion: aluminium, bakelite)	Shade: aluminium Arm: steel plate [Steel]	UV stabilized white thermoplastic plates Arm: aluminium	Polycarbonate (20% glassfiber) Reverse: black	Wood
	Diameter [mm]	117	117	100	89	88	88	76	200	130～120	105	1125 (W) 930 (L) 1511 (H)
	Length [mm]	475	457	370	358	423	586	630	420	270	238	
Ventilation speed *)	Measured	5.0 m/s	5.9 m/s	4.7 m/s *	4.3 m/s	2.0 m/s	2.5 m/s	3.6 m/s	–			
	Manufacturer	4 - 7 m/s	4 - 7 m/s	4 - 8 m/s	4 - 7 m/s	About 3 m/s	About 3-4 m/s	About 3 m/s				
Tdev : Temperature deviation [°C]	Daily Tmean 6 months *1)	Standard	-0.1 - 0.0 (-0.2 - +0.1)	-0.1 - 0.0 (-0.2 - +0.1)	-0.1 - 0.0 (-0.2 - +0.1)	-0.1 - 0.0 (-0.2 - +0.2)	-0.1 - 0.0 (-0.2 - +0.2)	-0.1 - 0.0 (-0.3 - +0.3)	-0.1 - +0.2 (-0.3 - +0.5)	-0.1 - +0.1 (-0.2 - +0.3)	-0.2 - 0.0 (-0.4 - +0.2)	-0.1 - +0.1 (-0.3 - +0.3)
	Daily Tmax Aug.		0.0 - +0.1	-0.1 - +0.2	-0.2 - +0.1	0.0 - +0.3	+0.2 - +0.5	+0.4 - +0.6	+1.1 - +1.4	+0.4 - +0.6	+0.1 - +0.3	+0.1 - +0.3
	Daily Tmin Jan.		-0.3 - 0.0	-0.3 - 0.0	-0.2 - 0.0	-0.3 - -0.1	-0.3 - -0.1	-0.4 - -0.2	-0.7 - -0.4	-0.3 - -0.1	-0.5 - -0.3	-0.1 - +0.1
	Effect of global solar radiation Aug. *2)		-0.1 - +0.1	-0.1 - +0.1	-0.2 - 0.0	0.0 - +0.3	+0.1 - +0.5	+0.2 - +0.6	+0.9 - +1.4	+0.3 - +0.7	0.0 - +0.3	+0.2 - +0.5
	Effect of radiation budget Jan. *3)		-0.3 - -0.1	-0.3 - -0.1	-0.3 - -0.1	-0.4 - -0.2	-0.4 - -0.2	-0.4 - -0.2	-0.9 - -0.4	-0.6 - -0.2	-0.7 - -0.4	-0.4 - -0.1
	Effect of rainfall *4)		0	-0.1 - 0.0	-0.1 - 0.0	0.0	-0.2 - -0.1	-0.1 - 0.0	-0.1	-0.1 - 0.0	-0.3 - -0.2	-0.1 - +0.1
Thermometer recommended		Pt 3 mmφ		Pt 6 mmφ		Pt 3 mmφ HMP155 etc.	Pt 3 mmφ	Pt 3 mmφ HMP155 etc.	Pt 6 mmφ	Pt 3 mmφ HMP155 etc.	HMP155	Pt 3 mmφ HMP155
Notes		JMA-95 for synoptic station		JMA-89 for old AWS	JMA-04 for AWS		Horizontal type alike PVC-03					JMA-1 louvered screen

*1) For the artificially ventilated screens/shields, the ventilation speed was measured using a Pitot tube indoors. This tube is the same length (100 mm) as the thermometer (Pt 100 Ω (3 mm in diameter)). In most cases, a 3.2 mm in diameter type was used. However, in case where this size could not be fixed, a shorter 3.1 mm in diameter tube was used.
*2) Tdev is in a range between 25% and 75% assuming that the maximum value is 100% and the minimum is 0% for each meteorological element. Positive Tdev is shown in pink and negative in light blue in cases where the value is more than ±0.2 °C. *3) Daily average temperature for 6 months (August, December, January, February, March and April) from the 10-sec. data. The values in ( ) show the minimum and maximum.
*4) 1 minute average global solar radiation data when the global solar radiation was 700 W/m2 or more in Aug. *5) 10-min. mov. ave. data when the radiation budget was −50 W/m2 or less in Jan. *6) 10-min. mov. ave. data when the rainfall intensity was Class 3 or higher (i.e., 2 mm or more for 10 minutes) for the 31 days when the total rainfall was 10 mm per day or more.

3.5 Comprehensive evaluation 3/3

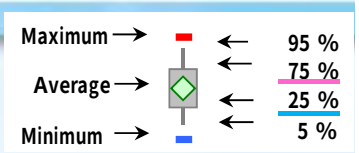
Table 2 Comparative table of operationally effective elements for each screen/shield

Ventilation		Artificially ventilated							Naturally ventilated			
Category	Type / Item	JMA-95(A)	JS-256(A)	E-834-Z1(A)	TV-150(A)	PVC-03(A)	PVC-02(A)	PFT-02(A)	AV-040(N)	YG-41003L(N)	DTR503A(N)	JMA-W1(N)
Cost performance	Electric power supply	△	△	△	△	△	△	△	◎	◎	◎	◎
	Periodic replacement parts	△	△	△	△	△	△	△	◎	◎	◎	◎
Maintenance	Ease of installation	△	△	○	○	○	○	○	◎	◎	◎	△
	Thermometer cleaning work	△	△	○	○	○	○	△	◎	◎	◎	◎
	Ease of maintenance	△	△	○	○	○	○	△	◎	◎	◎	◎
Weather resistance	Corrosion resistance	◎	◎	◎	◎	△	△	△	△	◎	◎	△
	Resistance to ultraviolet radiation	◎	◎	◎	◎	◎	◎	◎	◎	△	△	◎
	Insect resistance	◎	◎	○	○	○	△	△	△	△	△	△

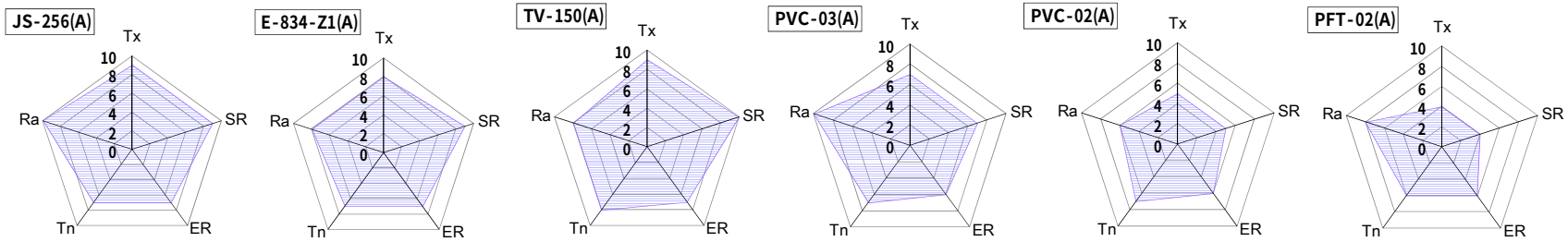
◎ better ○ normal △ not so good

3.5 Comprehensive evaluation 2/3

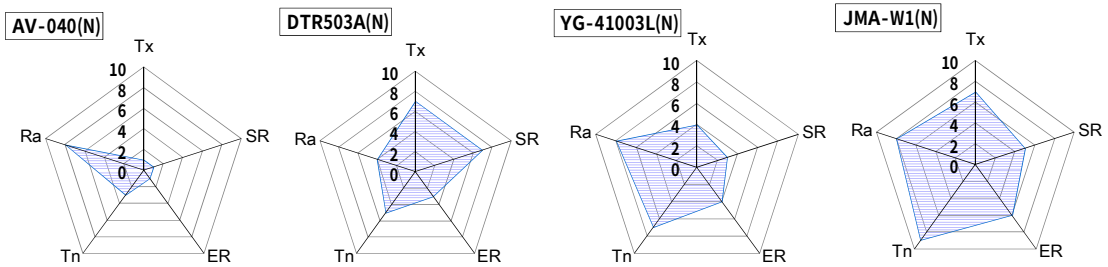
Fig. 10 Radar charts of Tdev differences related to various meteorological factors for each screen/shield



Artificially ventilated screens/shields



Naturally ventilated screens/shields



Item	Tx	SR	Tn	ER	Rain
Tdev [°C] / Class	Daily Tmax (Aug.)	Concerning global solar radiation (Aug.)	Daily Tmin (Jan.)	Concerning radiation budget (Jan.)	Concerning rainfall
10	0 -		0 -		0 -
9	+0.1 -		-0.1 -		
8	+0.2 -		-0.2 -		-0.1 -
7	+0.3 -		-0.3 -		
6	+0.4 -		-0.4 -		-0.2 -
5	+0.5 -		-0.5 -		
4	+0.6 -		-0.6 -		-0.3 -
3	+0.7 -		-0.7 -		
2	+0.8 -		-0.8 -		-0.4 -
1	+0.9 -		-0.9 -		

4. Discussion

(1) Influences of global solar radiation in August **:**

- Naturally ventilated screens/shields,
  - A maximum positive Tdev of **+3.4°C** for AV-040(N) is seen.
  - This influence produces the largest positive Tdev for AV-040(N) and the smallest for DTR503A(N)

  → The reasons for this are that the screen/shield **material** has **good insulation** and **the plates on the reverse are black**
- Artificially ventilated screens/shields, Tdev for PFT-02(A), PVC-02(A) and PVC-03(A) shows some influence

  → as these screens/shields have **no layer of insulating material**.

(2) Influences of radiation budget:

- Naturally ventilated screens/shields, a **negative** Tdev is seen. These negative values are observed for AV-040(N), DTR503A(N) and YG-41003L(N), in that order.

  → The reason is that the influence of radiative cooling differs because they have different thermal capacities and insulating materials.
- Artificially ventilated screens/shields, some negative Tdev is seen

  → due to differences in thermal capacity, insulating layers and the rate of ventilation.

(3) Influences of rainfall:

- Naturally ventilated screens/shields, higher rainfall intensity values give a more remarkably negative Tdev for DTR503A(N).

  → The reason is that its structure allows the internal thermometer to be seen between the plates from outside, and that it has a structure in which raindrops tend to remain on the flat edges of the plates.

  The structure of YG-41003L(N), in which no influence from rainfall is seen, has an internal thermometer covered by plates, In addition, the plates gradually become smaller from top to bottom and have an inverted dish shape,
- Artificially ventilated screens/shields, no difference in the influence of rainfall is seen.

5. Conclusions

- Naturally ventilated screens/shields
  - superior in terms of economy and ease of maintenance.
  - However, in cases where they are used in low-latitude regions, care is required because some types might be affected by strong global solar radiation.
  - It is also necessary to carefully consider the influence of the radiation budget.
  - as some are penetrated by rainwater and do not allow accurate temperature measurement.

Such screens/shields should also be used with a good understanding of their structure and characteristics,

- Artificially ventilated screens/shields

  - an essential requirement to minimize the influence of global solar radiation and the radiation budget is an appropriate insulation structure (insulation material/a heat-insulating layer of air).

- In addition, the horizontal type of artificially ventilated screens/shields requires care on rainy days because its configuration means that it is easily penetrated by wind and rainwater.

References

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- ISO (International Standardization Organization), 2007: Meteorology - Air temperature measurements - Test methods for comparing the performance of thermometer shields/screens and defining important characteristics (ISO 17714), First edition.
- Lacombe Muriel, 2008: Acquisition system used by the Algerian ONM for WMO combined intercomparison of thermometer screens/shields in conjunction with humidity measuring instruments, TECO-2008.
- WMO, 2008: Guide to meteorological instruments and methods of observation, seventh edition, WMO-No. 8.

Thank you for your time.

We would like to measure temperature more accurately all over the world, for our and children's future on the earth.

http://iss.jaxa.jp/shuttle/flight/sts99/photo_hdtv.htmlhttp://photojournal.jpl.nasa.gov/catalog/PIA11066

3.2 Influences of global solar radiation

Fig. 5 Time series representations of temperature for various screens/shields and solar radiation, 16 Aug. 2009 (summer)

(a) Temperature by various screens/shields

(b) Tdev for naturally ventilated screens/shields

(c) Tdev for artificially ventilated screens/shields

(d) Total global solar radiation