Field experiments to determine the effect of boundary fences on temperature observation

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Abstract

To minimize the extent to which warm air rising from artificial ground heat sources influences observation fields, the Japan Meteorological Agency sets screens or other types of boundary fences at certain weather stations. In this study, the effects of such fences on temperature observation data were determined via field and laboratory experiments involving 5.5 × 5.5-m areas surrounded by boundary fences with heights of 1.0 and 0.5 m on a large lawn at RIC Tsukuba. The results from thermometers placed with anemometers in the center of these areas showed slightly higher temperatures than when no fence was present.

1. Temperature observation in Japan

Growing concerns over global warming have necessitated greater accuracy in temperature observation on land and elsewhere (WMO, 2010). Against such a background, quality assurance (QA) for ground observation data is a major objective associated with the WMO Integrated Global Observation System (WIGOS), particularly in light of how meteorological observation has been significantly affected by environmental changes caused by rapid urbanization and other factors in recent years. However, at many weather stations in Japan, boundaries between observation fields and paved roads/parking lots have become indistinct. Winds arising from such heat sources bring warm air that may affect temperature monitoring data.

To minimize the influence of warm air on observations, the Japan Meteorological Agency (JMA) sets boundary fences or hedges with heights in the range of tens of centimeters. Many examples of such structures are now in place (Fig. 1). However, the lifting of warm air by these fences to the height of the thermometer (Oke, 1978) may affect observation temperatures. This applies in particular to maximum temperature values.

2. Necessity of experiments

No systematic studies on how boundary fences affect temperature observation had previously been conducted. Numerical calculation remains problematic in cases where fences or other types of permeable screen are present. To determine the effects of such structures, field experiments and/or laboratory experiments in a wind tunnel are necessary.

Figure 1 A boundary hedge around the observation field of an automated weather station in Japan

3. Overview of experiments

1) Field experiment

The field experiment was conducted from 2014 to 2015 in summer (approximately from July to September) and winter (approximately from December to March). Three observation fields (Fig. 2) were set on a large lawn at the Meteorological Instrument Center, also known as RIC Tsukuba. Each field had an area of 5.5 × 5.5 m, which is typical for JMA automated weather stations. Two thermometers were placed in the areas, one at a height of 1.5 m and one on the ground. An anemometer was also located at a height of 1.5 m. A 1-mm-mesh net was used as the boundary fence.

In 2014, two fields were enclosed with a four-face net at heights of 0.5 and 1.0 m. The other field had no net.

In 2015, one field was enclosed with a four-face net at a height 1.0 m as per the previous year. Another field was enclosed with a three-face net at a height of 1.0 m (Fig. 3) with the open face at the windward or leeward side.

The data recorded from this configuration were one-minute averages of temperature based on momentary values and ten-minute averages of wind speed/direction. Data for use were selected from conditions where the wind was almost perpendicular to the line of the three observation fields and cloud coverage had been less than 80% over the preceding six hours.

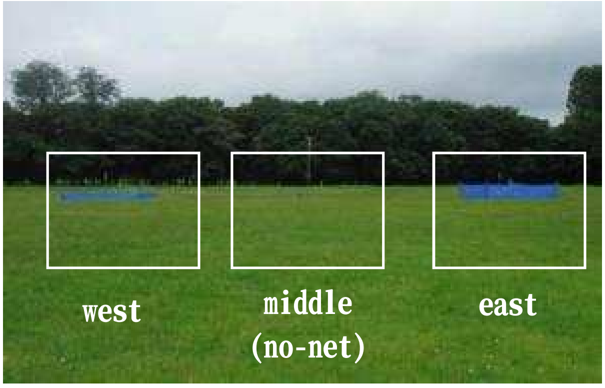

Figure 2 The three fields on the large lawn at RIC Tsukuba

Figure 3 Observational field enclosed in a three-face net with a height of 1 m

2) Laboratory experiment

The laboratory experiment was conducted in 2015 using the large wind tunnel at the Meteorological Research Institute. For this purpose, 1/10-scale models of an observation field (5.5 × 5.5 m) and a single-face boundary fence (height: 1.0 m) were created (Fig. 4). To enable flow pattern visualization, upstream wind with a uniform velocity of 3 m/s was generated with white smoke on the windward side of the fence.

To determine the movement of air parcels heated by the ground, monitoring was also performed to record the horizontal distribution of the mean concentration of tracer gas released from the tunnel floor, corresponding to air rising from a source on the ground. The gas was propane with concentration measured using a hydrocarbon analyzer at a height corresponding to that of temperature observation (1.5 m).

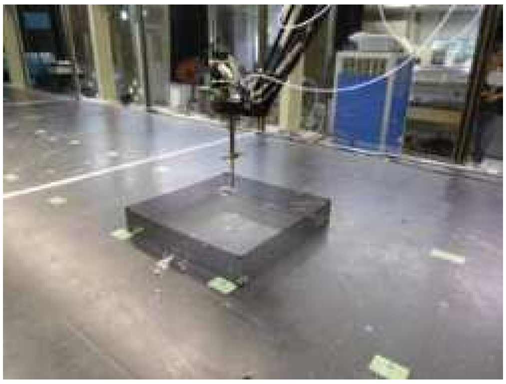

Figure 4 1/10-scale model of a fenced observation field on the wind tunnel floor

4. Results and discussion

1) Field experiment

The diurnal temperature in the field with the 1.0-m four-face net was higher (0.3 − 0.4°C on average in both summer and winter) than that in the no-net field, and the nighttime temperature was lower (0.1°C on average in summer and 0.3 – 0.4°C on average in winter).

The diurnal temperature in the field with the 0.5-m four-face net was higher (about 0.1°C on average) than that in the no-net field. There was no difference in the nighttime temperature (Fig. 5).

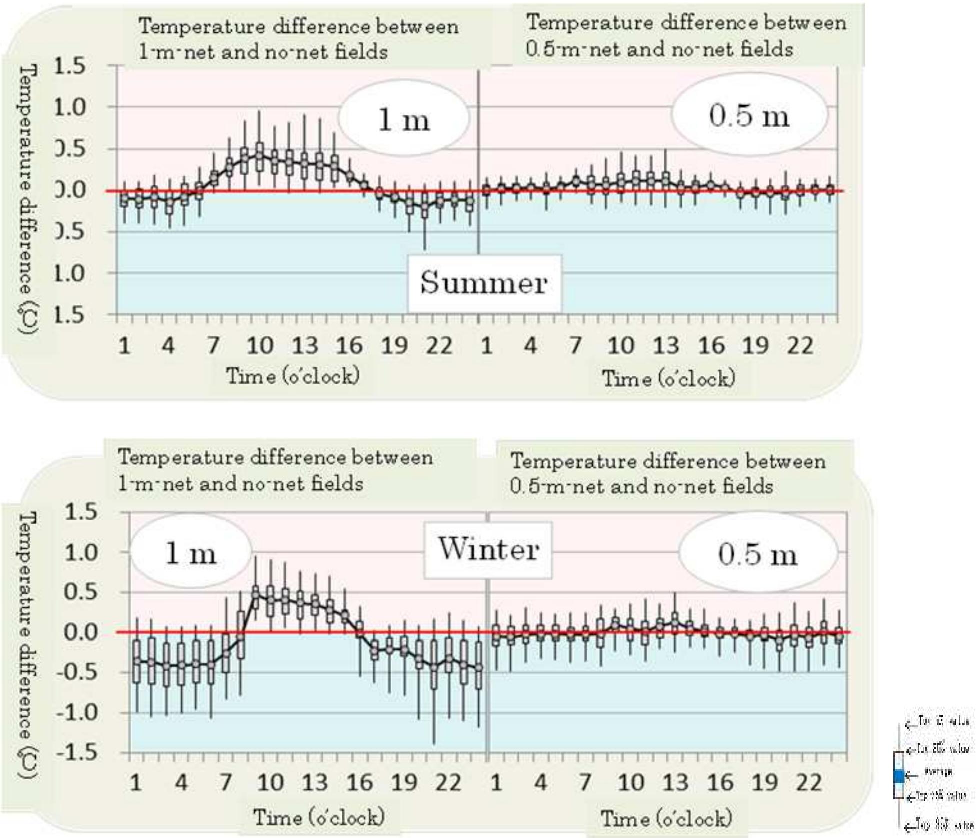

Figure 5 Temperature difference between the fields with four-face nets (1 m and 0.5 m) and the no-net field (no net)

The most significant effect on temperature was observed with the four-face net, then with the three-face net open on the leeward side, then with the three-face net open on the windward side. In the latter case, the observed temperature was almost equal to that of the no-net case (Fig. 6).

These results indicate that the effect of a boundary fence on observed temperatures is dependent on its height and configuration.

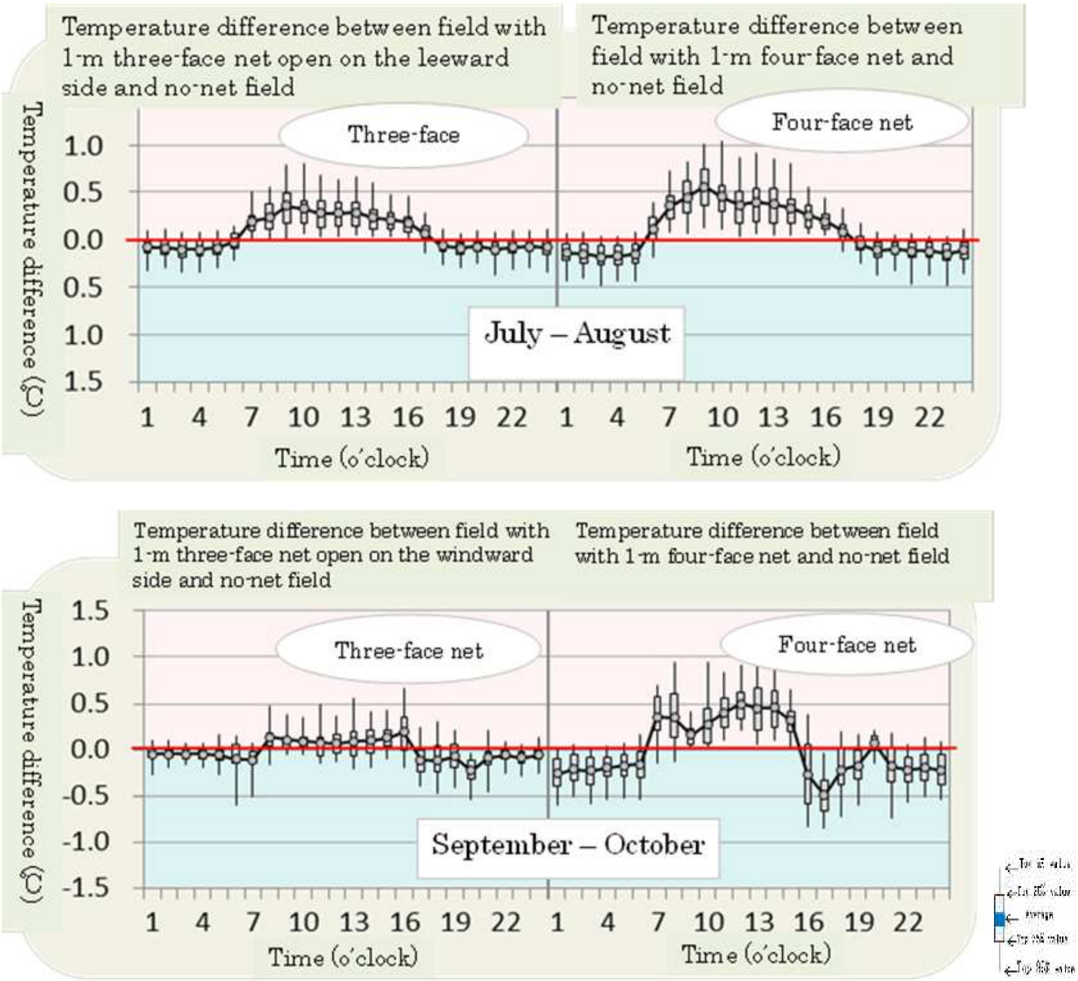

Figure 6 Temperature difference between fields with three/four-face nets and the no-net field

Top: summer (Jul. – Aug. 2015) Bottom: fall (Sep. – Oct. 2015)

2) Laboratory experiment

Visualization (Fig. 7) indicated that wind flowed over the fence and was lifted to the height of the thermometer. Flow circumventing the fence was negligible.

Consistent results were obtained from tracer gas monitoring. When the horizontal distance between the monitoring position and the gas source was less than the equivalent of 10 m in the full-scale field, gas was detected when a fence was present but not when there was no fence. That is, the gas in the presence of a fence was lifted to the height of the monitoring position. In the absence of a fence, the gas passed under the monitoring position.

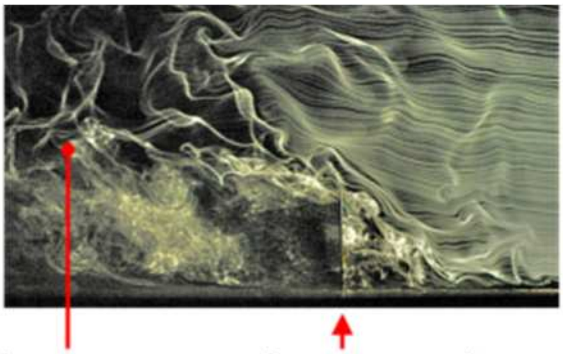

Figure 7 Visualization of flow over a fence.
The mean wind direction is from right to left.

5. Conclusion

The field and laboratory experiment results indicated that air rising from a ground source was lifted by the boundary fence to the height of the thermometer, affecting observed temperatures.

The outcomes of this study are expected to help clarify data uncertainties caused by the presence of weather station boundary fences. It is hoped that more comprehensive assessment to determine the influence of boundary fences on temperature observation based on these results will be made. Further research in the area is expected.

References

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