

Improving the WMO Guide n.8. Results on the experimental evaluation of the effect of presence of obstacles in the vicinity of sites hosting near surface meteorological measurement. The case of the road.

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The accuracy of near surface measurements of meteorological variables is influenced by the environmental characteristics of the site where the instruments are placed. Measurement results and recorded data can be subject to errors and uncertainty if the influence of the measuring site is not fully understood and evaluated. WMO guide #8 [1] establishes a qualitative/quantitative classification, by itemizing different site conditions, in terms of obstacles proximity, ground slopes, projected shades etc.

In the framework of the MeteoMet2 project [2], in order to deliver a validated analysis aiming at possibly improving the WMO siting classification, a one-year lasting experiment has been devised for evaluating the effect of obstacles on near surface air temperature measurements. The experiment consists in a 100-m long array of identical thermometers equipped with aspirated solar shields, placed on a flat grass field at increasing distances from an obstacle, such that the farthest station fulfils current WMO requirements for a Class 1 site.

Thermometers are Pt100 calibrated against reference standards and other quantities of influence are also measured: humidity, solar radiation, wind speed and direction. Three identical experimental setups have been designed, built and characterized to separately identify the effect of three different kind of obstacles: asphalt roads (Italy), trees (Czech Republic) and buildings (Spain).

Each experiment was set to acquire data for more than one year, and the acquired data was analysed exploiting a common and shared approach. The work here presented focuses only on the road siting experiment.

A statistical analysis based on Generalized Additive Model (GAM) was performed in order to understand the effect of each quantity of influence on the temperature measurements. Since the analysis was focused on the identification of a *worst-case* scenario, that is the largest possible temperature bias due to the influence of the obstacle, the model was instrumental in understanding the best combination of environmental factor that would boost the effect.

The GAM model was run on the difference of temperature between the measurements performed on the nearest (1 m) and the farthest (100 m) sensors with respect to the road ($\Delta T_7 = T_1 - T_7$) against all other ancillary measurements – wind speed (*WS*) and direction (*WD*), humidity (*H*) and solar radiation (*RAD*). The analysis showed a somewhat expected anti-correlation between ΔT_7 and *WS*, meaning that the largest values of difference in temperature was to be found at lowest values of wind speed, a more complex correlation with *WD* – suggesting largest values with winds coming transversally from the road and not perpendicularly – and an anti-correlation with *RAD*, meaning the largest values of difference in temperature was to be found at lowest values of solar radiation (at nights).

Results from the statistical GAM analysis was used to restrict the subsequent analysis to a much shorter temporal range: in this case, we chose to use only data coming at nights. During this phase of the analysis night plots of T_1 , T_7 and ΔT_7 were visually inspected to in order to separate temporally-

limited spikes – which may have been caused by a number of things and were not possible to link directly to the road siting effect – and longer, sustained and structurally more important differences. This analysis produced a limited number of important events that were analysed, also including data coming from the other sensors. This analysis produced a temperature difference profile that showed a slow increase in ΔT_i , going from the 100 m sensors to the closer ones, quantifiable in 0.4 °C at 50 m, 0.6 at 20 m, 0.75 at 5 m and rising up steeply to 1.1 °C at 1 m from the road.

Despite the lack of similar works in literature, comparisons have been made with the experiment by [3] and a theoretical study by [4]. While the experiment by [3] was different and with a different scope, a comparison between their findings and our ΔT_3 can be made, showing good agreement. The theoretical work by [4] also gives values compatible with our findings, especially within the first few m from the road, and lower values thereafter. This discrepancy can be due to a number of assumptions made during the simulation that were, besides a simplification, also tailored for the atmospheric and geographic particularities of the Japanese environment and may not represent the actual features of a different site.

An uncertainty analysis on these measurements has also been performed, including calibration uncertainties and measurement ones. The measurement uncertainties have been evaluated by dismantling the array and reassembling all the sensors in the same location for 4 months, in order to evaluate the relative different behaviour of the sensors exposed to the same environmental conditions. Together with considerations about other kind of instrumental uncertainties like sensors self-heating, shield ageing, sensor drift and electrical contributions of the datalogger, the overall (k=2) uncertainties for these temperature differences can be evaluated between 0.2 °C and 0.5 °C.

[1] WMO-N°8 [WMO Guide to Meteorological Instruments and Methods of Observations, 2014 edition \(updated in 2017\)](https://library.wmo.int/opac/doc_num.php?explnum_id=4147), https://library.wmo.int/opac/doc_num.php?explnum_id=4147

[2] Merlone, A. et al "The MeteoMet2 project – Highlights and results" 2017 Meas. Sci. Technol. <https://doi.org/10.1088/1361-6501/aa99fc>.

[3] Kumamoto M., Osuka M., Sakai, T., Hamagami T., Kawamura H., Aoshima T., Fujibe F., 2013. Field experiment on the effect of a nearby asphalt road in temperature measurement, *Scientific Online Letters on the Atmosphere*, vol 9, 56-59, doi:10.2151/sola.2013-013

[4] Kinoshita, N., 2014, An evaluation method of the effect of observation environment on air temperature measurement, *Boundary-Layer Meteorol*, 152:91-105, DOI:10.1007/s10546-014-9918-2