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Statistical analysis and clusterization of environmental parameters measurements from co-located sensors



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DI TORINO

Abstract

One of the most difficult things in metrology for the environment is the evaluation of measurement uncertainties. Air temperature sensors are influenced by many external factors, such as solar radiation – both direct and diffuse – humidity, wind speed and direction. Laboratory calibration is necessary but not sufficient for a comprehensive understanding of the behaviour of air temperature sensors while subject to the wide variety of environmental conditions they meet in normal operation.

This work follows up the one by Coppa et al., (2021), where the evaluation of uncertainties of commercially available air temperature sensors and shields was computed by a dedicated experiment, where 7 sensors were co-located for 2 months. In that work, uncertainties were evaluated simply by computing standard deviations of temperature differences between each sensor and one taken as a reference.

The road siting effect evaluation experiment



The present work provides a more refined uncertainty evaluation by a statistical method, through machine learning and clusterization, in order to evaluate uncertainties in dependence on the environmental conditions.

Temperature differences during the co-location experiment have been run through an unsupervised k-means algorithm that revealed several clusters: in particular, temperature differences are lower, thus leading to smaller uncertainty, under two very different environmental conditions: the first, at nights with very low winds; the second during high-radiation and high-wind days.

Unsupervised k-means clustering algorithm

3D Scatter Plot

3D Scatter Plot





Temperature differences can be corrected by subtracting the cluster centroid value from each observation, while uncertainties can be taken as the standard deviations of each cluster distributions, then associated to each sensor+shield system depending on the specific environmental conditions (evaluated by ancillary measurements). This methodology reduces the overall uncertainty and improves the level of detail about sensors behaviour knowledge.

	Δ Τ (°C)	Rad (W/m ²)	RH (%)	Wind speed (m/s)		$oldsymbol{\sigma}_{\Delta T}$ (°C)	Variation
Cluster 0	<mark>0.047</mark>	7	94.0	0.71	Cluster 0	0.045	<mark>43%</mark>
Cluster 1	0.352	192	71.0	0.73	Cluster 1	0.120	<mark>115%</mark>
Cluster 2	<mark>0.109</mark>	207	54.1	1.24	Cluster 2	0.070	<mark>67%</mark>
Cluster 3	<mark>0.051</mark>	106	49.9	3.11	Cluster 3	0.055	<mark>53%</mark>

Cluster centroids of the 4 different parameters.

Standard deviations of ΔT measurements and variation over previous evaluation.

Conclusions

- A way to refine the evaluation of measurement uncertainties in air temperature, is presented.
- A clustering algorithm to group together measurements taken in similar conditions is used
- Centroids as bias corrections
- Standard deviations of cluster as uncertainties
- Uncertainties for the largest part of measurements are reduced

Future work

Extend to longer time periods (whole year) **Explore other clustering algorithms**

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