Proposed guidelines on microclimate measurements in tropical cities

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Background

Field measurements are fundamental to urban microclimate studies. The advantages include acquiring direct evidence of the 'real-world' microclimate conditions, and portraying reliable results with a high temporal resolution as first-hand information. Microclimate studies that assess the thermal or human-biometeorological effects of the urban environment are often based on field measurements. Existing guidelines and standards for meteorological observations serve to clarify and standardize the measurement process. These include *The Guide to Instruments and Methods of Observation* (WMO No. 8 guideline), ISO 7726 and ISO 7730 Standard, and the ASHRAE handbook.

However, a review of field measurement studies over the last five years has identified four common pitfalls that call for improvement: (1) measurement designs; (2) field measurement preparations; (3) operational procedures; and (4) metadata records. The primary concerns are the inappropriate application scale and location, and the lack of a systematic workflow, both of which can limit data quality and applications. To address the lack of comprehensive and systematic guidelines, researchers from Hong Kong collaborated to propose a guideline with a systematic and actionable workflow of microclimate field measurement procedures for application in urban areas.

Introduction of the guideline

This guideline proposed a systematic approach to conduct microclimate field measurements at the pedestrian level in cities. It aims to ensure the systematization and reliability of observations by standardization, preparation, and precaution. The guideline is based on research experiences in the tropical zone, applicable sections from existing guidelines/standards, and recommendations from professionals. The complex and heterogeneous environment in urban areas was carefully evaluated to hone the data acquisition campaign and ascertain data quality. Four steps in microclimate field measurements were elaborated: formulating a field measurement plan, preparing for field measurements, sustaining measurement quality, and curating data (Fig. 1).

In the first step, *formulating a field measurement plan*, the guideline listed seven aspects that should be carefully considered before conducting measurement campaigns. These include: establishing clear measurement objectives, determining field measurement type, selecting and characterizing field study sites, ascertaining microclimate variables and instruments, selecting a reference station, choosing the field day weather, and deciding the field date and time.

In *preparing for field measurements*, the guideline emphasizes the significance of instrument calibration and maintenance. Precautions for developing a weather monitoring system are introduced. The guideline also offers detailed memoranda of organizing measurements, such as seeking permission for site access, preparing accessories and spare parts, and preliminary testing.

In *actual measurement campaigns*, the guideline pinpoints four aspects demanding careful consideration. These include checking equipment and data storage regularly, keeping an observation log, responding to unexpected conditions, and collecting meteorological data for the field day.

In the *data curating process*, the guideline highlights some issues that may affect data analysis, such as formatting data, processing data, and controlling data quality.

Unique features of the guideline

Focusing on urban-environment characteristics at the micro-scale

The urban microclimate is a complex and heterogeneous consequence of diverse parameters involving a wide range of natural and urban processes. The microclimate of high-density cities is strongly affected by high-rise buildings, narrow street canyons, inhomogeneous urban fabric, changeable anthropogenic heat/cooling/moisture, diverse vertical and horizontal exchanges of momentum, and complex human activities. Therefore, the complicated urban milieu is not amenable to many existing guidelines for site selection and instrument exposure. Therefore research design should consider specific principles and concepts unique to urban areas to ensure meaningful observations. This guideline avoids offering rigid rules due to considerable spatio-temporal variations in the environment. Instead, it guides researchers towards intelligent and flexible applications to match the complex and often unique realities of the specific study site.

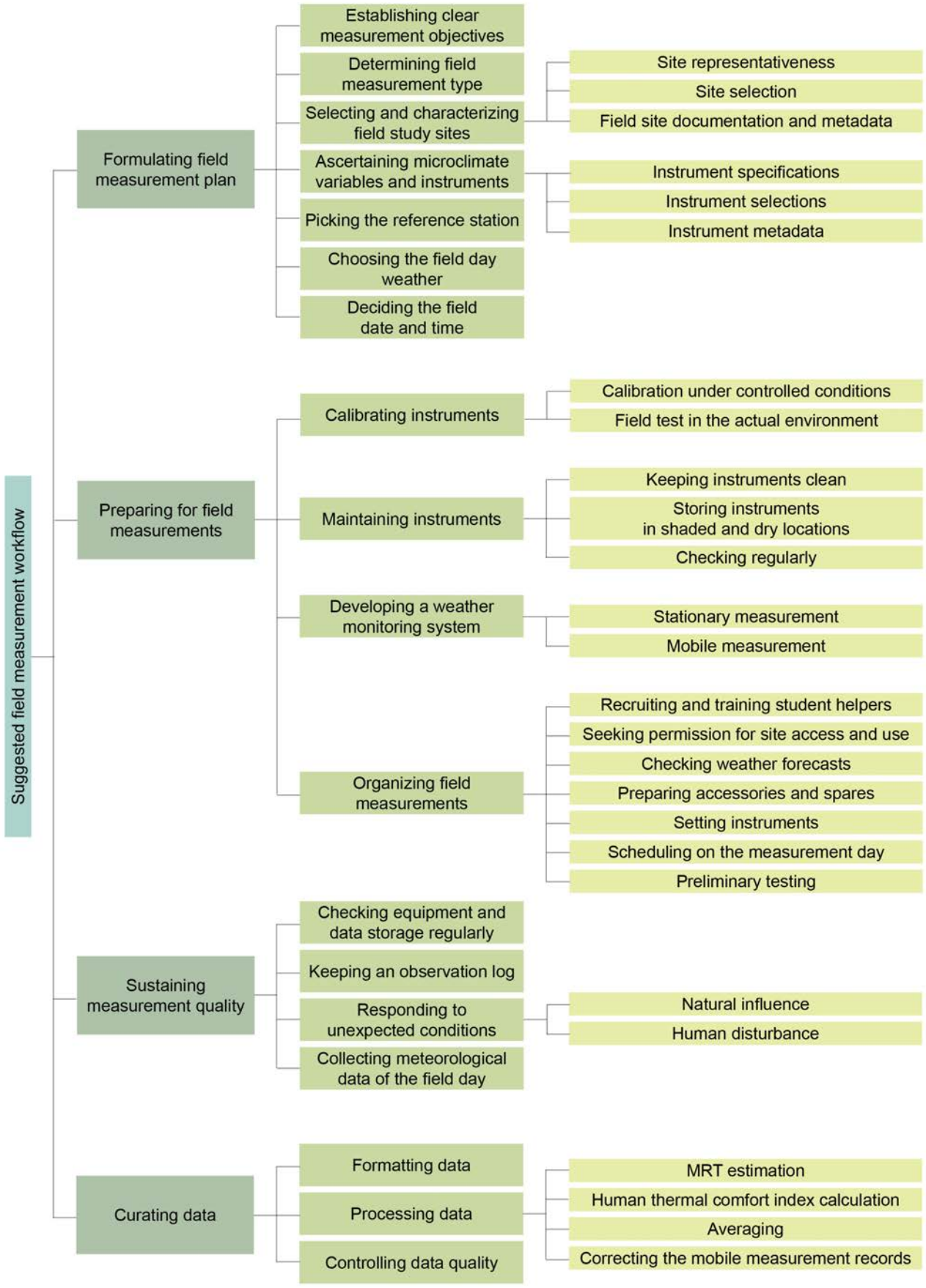

Figure 1. The suggested field measurement workflow and proposed steps.

Designing a systematic workflow and comprehensive information protocol

In conducting field measurements in urban areas, it is necessary to adopt a flexible approach and apply guiding principles rather than rules. This guideline provides researchers with a systematic and comprehensive field measurement workflow, providing a clear path to consider every detail in urban microclimate field measurements. It presents a holistic experimental workflow, including the pre- and post-processing. Relevant concepts and practices learned from existing guidelines and standards, experiences from actual field studies, and recommendations from professionals are distilled and incorporated into the document.

Emphasizing the need to keep complete metadata

According to the WMO (World Meteorological Organization), all information or data about observations, e.g., how, where, when and by whom the data were recorded, gathered, transmitted and managed, is called metadata. It is essential to keep a complete metadata record because any absent or missing parts could incur difficulties attributing any variations over time to changes in climate. The Global Climate Observing System (GCOS) Climate Monitoring Principle describes the significance of metadata as "(Metadata) should be documented and treated with the same care as the data themselves". However, almost none of the reviewed articles reported comprehensive metadata. Further, the significance of a complete report, i.e., incorporating the full metadata, has seldom been prescribed or stressed in previous field measurement studies. This pitfall has been duly emphasized in our guidelines. A comprehensive metadata checklist, including all necessary items, definitions, and examples, has been provided for reference. Complete metadata can ensure comparability among studies, enabling further meta-analysis.

Providing enriched materials for illustration and reference

Detailed hints, precautions, recommendations, examples, and checklists are provided in the guideline as a helpful and actionable package of research procedures. Examples of quantitative local meteorological descriptions, site aerial photographs and ground images (Fig. 2), self-developed weather monitoring systems (Fig. 3-4), etc., are provided for illustration and reference. With these enriched materials, researchers can obtain clear and direct prompts to design their studies.

Epilogue

This proposed guideline significantly contributes to refining systematic field measurement methods at the microscale in urban environments. Researchers are recommended to consult this guideline in planning the collection of urban microclimate field data.

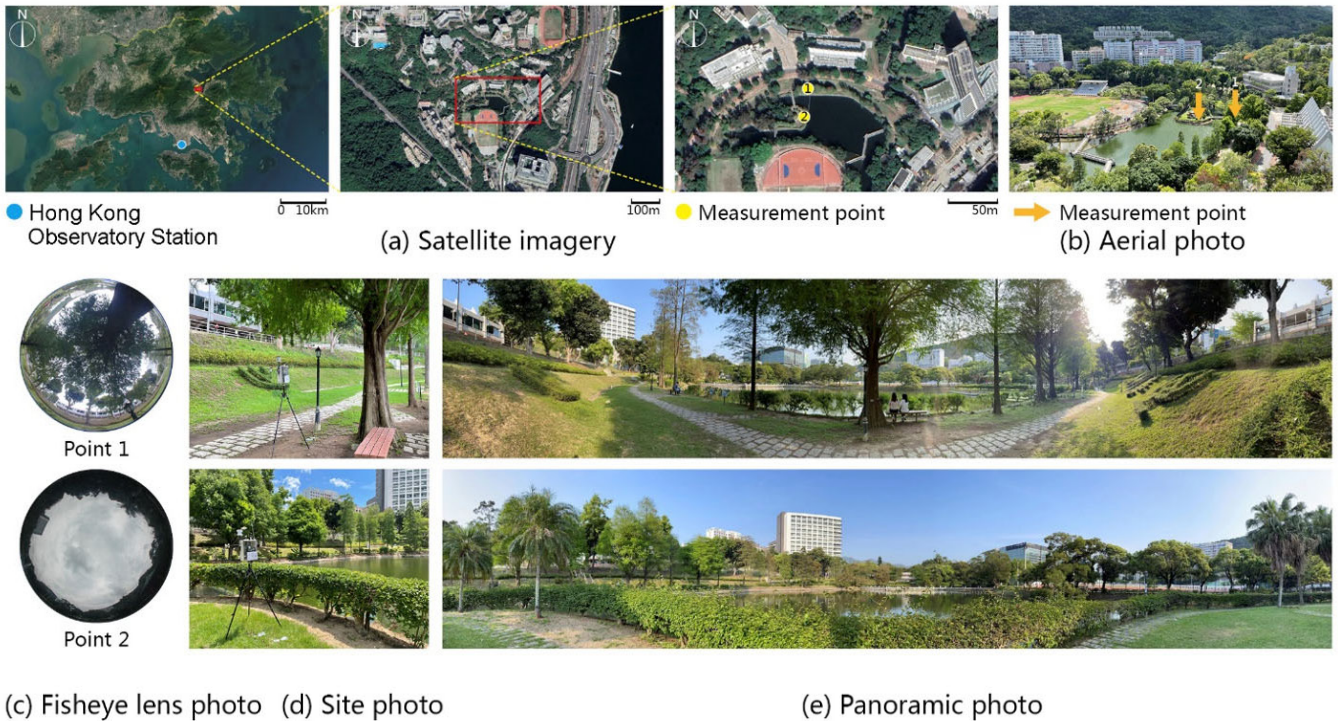

Figure 2. Examples of site aerial photographs and ground images in the guideline.

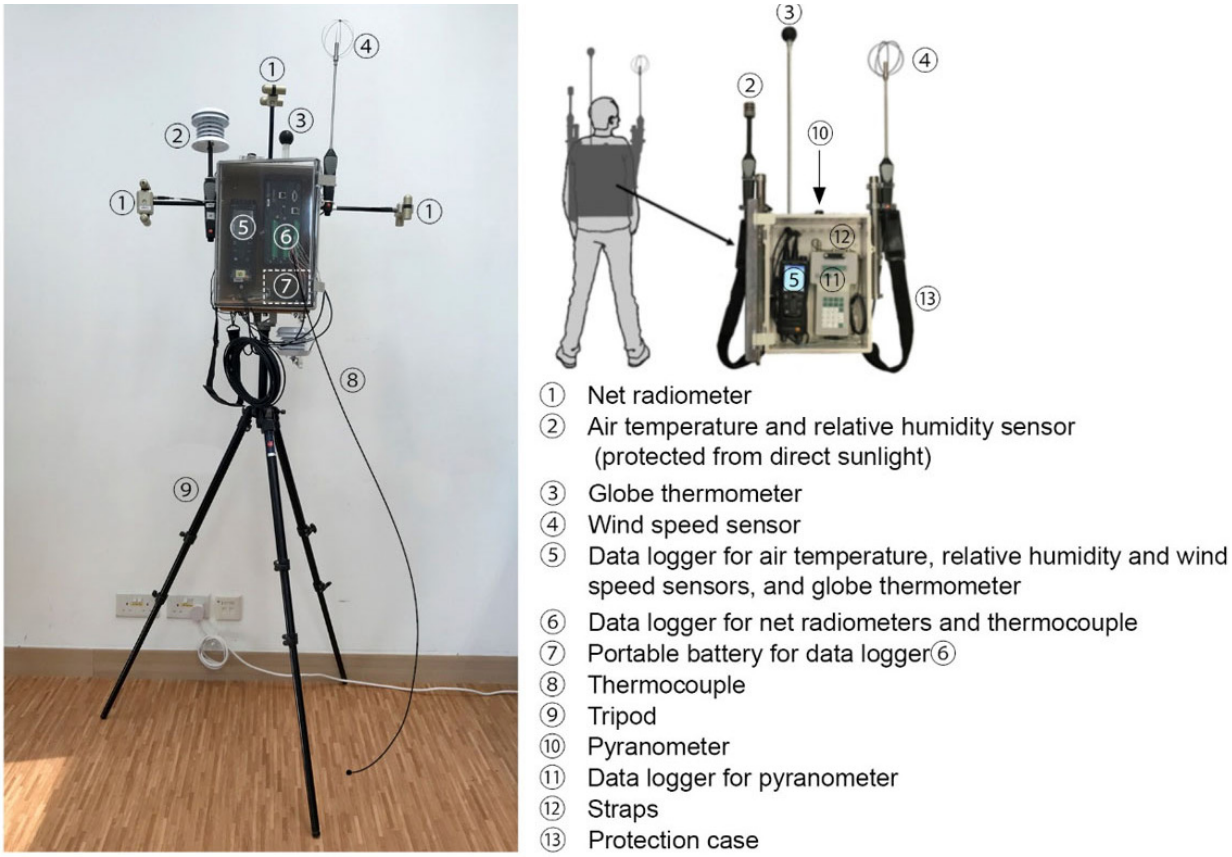

Figure 3. An example of the self-developed weather monitoring systems in the guideline.

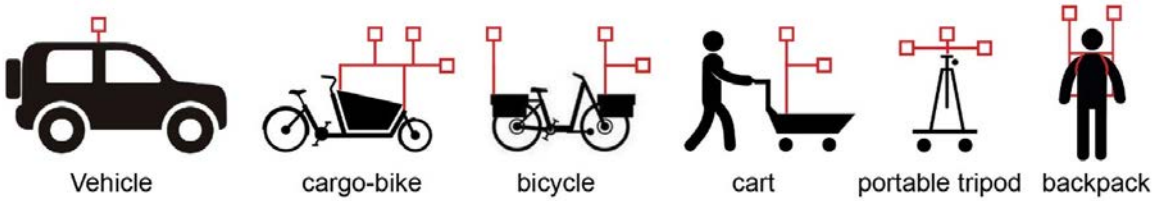

Figure 4. Various mobile measurement systems showed in the guideline.

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