Mobile Integrated Automatic Weather Station for Real-Time Data Acquisition and Analysis

Nanna Sri Ramya[1*], *K Anand Goud* [1], *Gundurouthula Srikanth*[2], *Basireddy Bhavani*[1], and *Bagu Maanasa*[1]

[1]Department of Civil Engineering, Institute of Aeronautical Engineering, Hyderabad, 500043
[2]Department of Civil Engineering, Pallavi Engineering College, Hyderabad, 501505

Abstract. A mobile-integrated Automatic Weather Station (MI-AWS) enables the acquisition of real-time weather data and analyzes the measured meteorological parameters such as rainfall, atmospheric pressure, relative humidity, temperature, and wind speed and direction. Utilizing cost-effective sensors connected to the microcontroller facilitates the collection of continuous data, which is then transmitted to the mobile application. The collected data can be used for remote monitoring, visualization, and cloud-based storage. This MI-AWS system overcomes the limitations of traditional weather stations. It provides an easy-to-use and scalable way to forecast weather, monitor the environment, and tackle disasters. The present study aims to monitor the weather at different locations in the Dundigal region and give early warning signs or precautions to the locality if needed. This study helps to moderate the impact of intense weather conditions, viz., storms, floods, high temperatures, humidity, and wind speed, supporting the decision-making in sectors such as transportation, aviation, agriculture, and public safety. The mobile-integrated, low-cost design enhances access to exact weather monitoring, fostering environmental resilience and ensuring improved public safety through timely and reliable data.

Keywords: MI-AWS, Mobile applications, Real-time, data monitoring, Weather forecasting

1 Introduction

Weather monitoring is very crucial nowadays, as it impacts urban growth, human health, and the development of agriculture. Traditional weather systems are reliable, but there is a lack of monitoring, which is not very feasible for accessing the real-time, continuous data. By utilizing modern tools, it is possible to access real-time data regularly, and it has flexibility. MI-AWS is developed to monitor the weather data continuously using sensors at the locations or stations. These stations use sensors to measure the weather parameters, viz., temperature, humidity, wind speed, rainfall, and atmospheric pressure. This MI-AWS provides a simple and flexible way to continuously monitor weather data and transfer it to cloud platforms via mobile networks, allowing for quick and informed decision-making. The mobile technology

* Corresponding author: n.sriramya@iare.ac.in

in MI-AWS has many advantages that make it more effective for others to use. As mobility allows these stations to be brought around, along with reduced investment in fixed structures, it particularly proves helpful when such monitoring traditionally is not established in remote and rural areas. Remote access allows the user access to real-time data and has changed the way humans react to rapidly changing weather phenomena. It benefits areas like precision farming, the disaster response initiative, and city air quality management. These applications can really improve the communities preparing for and handling weather-related events.

The conditions of the atmospheric weather at a specific period and place contain different essentials such as humidity, temperature, precipitation, wind, and cloud cover [1]. These variations in the climate may disturb the daily routine, so it is important to take accurate measurements of the climatic conditions at particular locations or stations. The data collection is critical for understanding the weather conditions, which helps in forecasting the climate pattern. A conventional weather system is used for measuring the temperature, humidity, solar radiation, rainfall, wind speed, and its direction to deliver an overall assessment of the local weather conditions. For this case, there is the WatchDog mobile application, which is an unconventional system with MI-AWS [2]. This displays several crucial environmental constraints in real time, such as temperature, rainfall, relative humidity, wind direction and its speed, and solar radiation. This device affords consistent data that assists in many areas, such as environmental studies, farming, and public safety. Its robust construction allows it to function in various outdoor environments, plus it records long-term data implying its persistent operation even away from human perception. WatchDog MI-AWS also provides a wireless data broadcast from which operators can access online weather information remotely via mobile devices or use cloud services making a must-have at many remote locations that require up-to-the-minute weather updates.

2 Review of Literature

Automatic Weather Station provides real-time data and the basic understanding of urban city climates, highlighting the advantages [1] in collecting high-resolution meteorological data from a large number of small APWSs to understand different local climate and surface heat island effects. Cabrera found that mobile phones could represent the evolution of weather stations AWS into domains driven by cellphones and Internet of Things platforms for massive sensing data harvesting, urban measurement in real-time. In line with this, the smart weather stations for IoT that characterise the improvements in sensor networks, wireless communications (LoRaWAN devices), and cloud-enabled data management which can increase the scalability and cost-effectiveness of IoT-AWS [3-4]. After the AWS network and data sensing [5], he showed a few georeferenced techniques for Comfort measurement of the transient. Lau studied spatiotemporal variability and pedestrian thermal comfort illustrating the ability to investigate fine spatial scale urban heat island mapping using AWS data [6-7]. Relates analyses to thermal perception in hot arid cities, highlighting the contribution of AWS data in disentangling hidden urban microclimates [8]. Mobile road weather stations sensor fusion and calibration [9] as well as data integrity in dynamic environments.

Their work revisited the reliability of citizen weather stations and gave quality control examples, revealing challenges in calibrating AWS on centric point [10]. Crucial mobile stations improvements via crowd source. Barbano [11] assesses the performance of mobile outdoor weather sensors and argues for implementing energy-efficient (solar powered) automatic weather stations (AWSs) to maintain continuous monitoring at remotes sites. Thus, it is exactly this Koopmans which introduces high-resolution (1m) urban heat maps based on

AWS. Heusinkveld quantifies spatiotemporal urban heat island differences caused by land use using dense AWS sensor networks.

3 Methodology

The location and mounting configuration of MI-AWS primarily contribute to accurate measurements of meteorological data. To present well, the automatic weather station should be set up in a clear grassy area free of obstructions. A place or position that guarantees the correct readings of rainfall, wind speed and direction, precipitation, and sunlight without interference from neighboring buildings or plants. MI-AWS IP Installation: The MI-AWS is generally installed on a pole sized in the range of 1.25 to 1.66 inches (32–42 mm) with a wall thickness of about 0.13 inches (3.3 mm). The sensor should be deployed in the vertical orientation approximately 6 feet (1.8 m) off of the ground with a 1.5 inch (40 mm) pole for accurate rainfall measurements. If a pole of that size is not available, but a tripod (like those from Spectrum Technologies) may be used. For installations at higher elevation, guy the pole with support wires since strong winds could cause it to sway. Obstacle this to data acquisition in real-time: MI-AWS mobile app with sensors to measure humidity, temperature, wind speed and rainfall These data are processed through microcontrollers and get transferred wirelessly through means of Wi-Fi or GSM. On the app, or web interface online, users can pull up live readings and even extreme weather push notifications. Machine learning models thrive on historical data that in the end leads to better forecasts. Long-lasting use is achieved by calibrating the sensor, encrypting data and allowing it to run on solar energy.

This MI-AWS can then be attached to any Smartphone via the free WatchDog Mobile app which facilitates correct set up and configuration. MI-AWS WatchDog mobile app can also be used for realtime collection of weather variables along with some other key parts as shown in the Figure 1. Gathering data from sensors on key meteorological variables e.g. humidity, temperature, wind speed and rainfall The processed data, using a microcontroller, is transmitted through wireless technologies (e.g., Wi-Fi or GSM). A mobile application (and web interface) allows users to view real-time data, and receive alerts for severe weather events. These are predictive methods based on machine learning that also take into account past data. This also typically includes regular sensor calibration for both efficiency and reliability; secure data encryption; and a sustainable power supply – often solar-powered. Free WatchDog Mobile app to connect users smartphones to MI-AWS and guide them through the configuration for proper operation.

Fig. 1. WatchDog 3000 series product

Mi-AWS application configuration: The WatchDog mobile application is synchronized with the automatic weather station device to a smartphone (mostly family package installations are made through Google Play Store or Apple App Store). Smart phone version for the WatchDog Mobile application. Ensure the app was updated (up-to-date) before doing so. Long press 「Select」 key to turn on Bluetooth in MI-AWS It will illuminate the Status LED and flash once every second, in addition to displaying battery percentage: green 80% or higher, amber under 80%, red under 40%. Open the app and connect either via Bluetooth by tapping a "Bluetooth" button or signing in to SpecConnect for data transfer. Select the station's serial number in the Bluetooth Devices screen to proceed with setup. You remember to set the location and zone time optionally. Finally for 3000PP Stations configurations, the radio channel has to be defined too before saving. Cell and Wi-Fi models will automatically sync to SpecConnect — typically within five minutes following configuration. Micronetwork Connection The MI-AWS mobile application will allow the user to connect to a Wi-Fi network by entering the Access Point name (SSID) and password. When completed with this, head over to configuration screen in other tab WiFi Settings. Enter the Username and Password of the network and save.

Tap the station's serial number to check for a Wi-Fi connection, then select one of the parameter icons to view the real-time weather data. It may take about a minute for the new readings to appear; you will know they have updated when the "Time Since Last Upload" value resets from "0 minutes". This process ensures that the MI−AWS has been integrated with the Wi-Fi network for real-time meteorological monitoring. Equipment Status screen with WatchDog mobile apps to show the effective weather Conditions screen: In this screen---Tap on a Station then tap Thermometer icon. This MI-AWS screen will show the readings from the sensors, along with the serial number of the stations and date and time when data was updated last. You can click each of the icons to view a chart showing types of weather occurring over a period of 24 hours. Long press on the graph to activate the trackball, which lets you find precise numbers at given points in time. Yellow star icons show the parameters that were favorited in WatchDog App Favourites — with the star toggle Favourites– this feature is for fast access to parameters that are often watched, so you can effectively search station data and trends. WatchDog MI-WAS is a management and visualization based interactive tool that combines live monitoring data together in a single comprehensive platform ensuring accessibility to operators from remote locations. This simple access allows the monitoring of climatic or environmental parameters with great affluence.

4 Results and Discussion

It gave us information on either amount of rain fall in different seasons (like summer, Rainy and winter) and also temperature, wind speed, humidity as well as wind direction from the WatchDog MI-AWS mobile application. The weather parameters for the summer season, recorded on eight selected dates between March and May 2024, are shown in Table 1. Two different dates in September were deliberately selected to examine the variations of temperature, relative humidity, wind speed and rainfall at two stages of the seasonal changes. These readings (26–27 March, supplementary file 1) may be classified as early summer readings with moderate temperatures (31.4–37.6 °C), and a relatively high humidity of about 60–62%. The observations from mid-April (19–20 April) corresponding to the pre-peak summer stage with rising temperatures (40.5–41 °C) and winds stronger (up to 22 km/h) also from the southeast, that probably impacted in small rain precipitations (0.9–1.3 mm). The peak summer conditions are reflected in the early May readings (3–4 May) which show temperatures highest (42.5–43 °C), humidity lowest (50–52%) and wind speeds greatest from south, together with maximum rainfall intensities now quite heavy for Khammam when compared to earlier periods (up to 2.32 mm), possibly associated with pre-monsoon thunderstorms.

Table 1. Data in the Summer Season

Date	Temp	Humidity	Wind speed	Wind direction	Rainfall
26-03-24	31.4	60	10	E	1.0
27-03-24	37.6	62	12	E	0.8
19-04-24	41	55	15	SE	0.9
20-04-24	40.5	57	22	SE	1.3
03-05-24	43	50	20	S	2.32
04-05-24	42.5	52	18	S	1.0

Similarly, the rainfall data were divided by season, with October 2023 used as the reference point for training on the same weather data (Table 2), and the winter season data presented separately in Table 3. This dataset, together with the others, allows a comparative analysis of rainfall distribution, temperature trends, humidity variations, and wind characteristics across different climatic periods. These comparisons help in drawing inferences about the seasonal variations that influence local weather conditions.

Table 2. Data in Rainy Season

Data	Temp	Humidity	Wind speed	Wind direction	Rainfall
27-06-24	27.29	89	13	SW	4.42
28-06-24	26.75	83	18	WSW	3.0
22-07-24	25.89	85	15	WSW	3.89
23-07-24	27.04	91	10	W	2.4
09-08-24	24.9	87	20	SW	1.6
10-08-24	27.4	89	22	SSW	3.36

Table 3. Data in Winter Season

Data	Temp	Humidity	Wind speed	Wind direction	Rainfall
25-11-24	30	70	10	E	1.80
26-11-24	27	68	12	E	1.4
12-12-24	20	60	8	NE	1.19
13-12-24	18	62	10	NE	0.7
06-01-25	22	55	6	W	0.7
07-01-25	23	57	8	W	0.6

The mobile-integrated MI-AWS are shown to be best suited for collecting and analysing various local meteorological data in real-time providing crucial advice on the local weather conditions. An automatic recording of crucial metrics like temperature, humidity, wind speed as well as direction is done in order to ensure accurate measurement. The system sends data through remote access in real time with mobile connectivity for use in weather predictions, agricultural purposes, disaster management and infrastructure planning.

Temperature: Temperature data were characterized by two seasonal differences: summer (April and May), rainy (June and July), winter (November と December). Warmest temperatures of summer — all above 40 °C — caught up with May that was still slightly warmer than April. During the rainy season, temperatures decreased to around 27–28 °C presumably due to increased cloud cover and rainfall (Figure 2 meant). Those coldest numbers occurred during the winter when the average dropped to 26 °C to 30 °C in places that usually sit somewhere between warm and hot. This trend is a common seasonal feature of all tropical and subtropical regions, as solar heating peaks to extreme levels near mid-summer, clouds bring relief through cloud cover with moist warm / wet time-year-season induced via convective equilibria — thus winter brings no less support for milder weather when low-angle sunlight is nearly absent. This variability is important information for the decision making on agricultural practices, since if temperature feedback out of phase changes across seasons affect plant development by impacting water and pest activity (6). They also help with demand reduction strategies for summer cooling and winter energy performance.

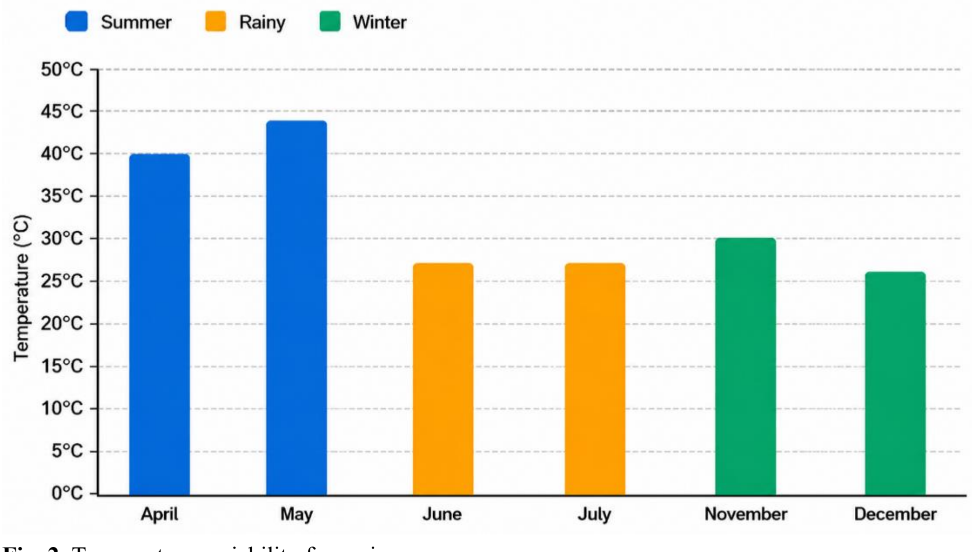

Fig. 2. Temperature variability for various seasons

Humidity: This plot shows the variation in humidity for each major season (summer: April and May; rainy: June and July; winter: November and December). The highest humidity occurred during the rainy season, with mean values of approximately 89% in June and just above 90% in July. This elevated moisture content results from frequent rainfall and the saturated air masses characteristic of the monsoon. In contrast, the summer months recorded average humidity values of 57% in April and 52% in May (Figure 3), reflecting the drier air produced by high temperatures and intense solar radiation, which increase evaporation without adding atmospheric moisture in the absence of rainfall. The winter months showed intermediate values of about 70% in November and 61% in December, reflecting cooler, drier post-monsoon conditions without the residual moisture of the wet season. These humidity variations are important for agriculture, human comfort, and various ecosystem processes, as they directly affect plant transpiration, the spread of disease, and local climate dynamics.

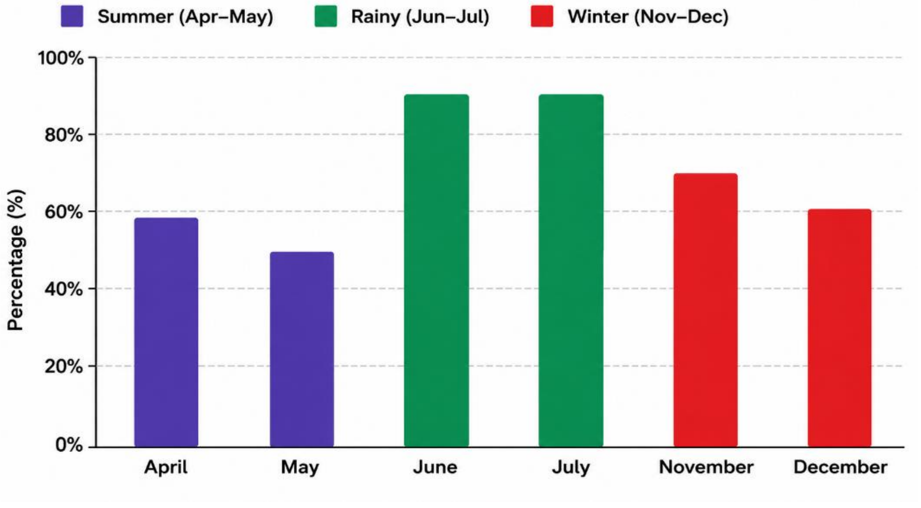

Fig 3. Humidity variations for different seasons.

Wind speed: Seasonal variation: annual wind speed from April to May, summer (rainy) June and July, and winter November and December. However, winds were raised to some point through the summer months, with 22 km/h for April and close to 20 km/h for May -- localized pickings which know when effectual only one time (probably a good deal more) by chain localization due to eminent surface heating forward doing much greater air support in met condition depending on bracing winds. Lower wind speeds during rainy season were also observed with average gonioscope derived horizontal wind speeds at about 18 km/h in June and 15 km/h in July (see Fig. 4). At the surface, heavy rainfall and more stable atmospheric moisture lock in warmer air as strong wind flows above are forced to drop. MI-AWS inputs on wind, humidity and temperature to achieve uniformity of results at the same time. Their lowest wind speeds were recorded during the winter, with an average of 12 km/h in November and approximately 10 km/h in December. Colder material aloft at places and times like this of the year suppresses convection — in common, a peaceful environment. These seasonal wind shifts have implications not just for agricultural production, but for the feasibility of wind energy development and for local climate comfort: faster winds associated with these changes bring increased evaporation rates, mix out pollutants (sometimes improving air quality), and contribute to perceived temperatures.

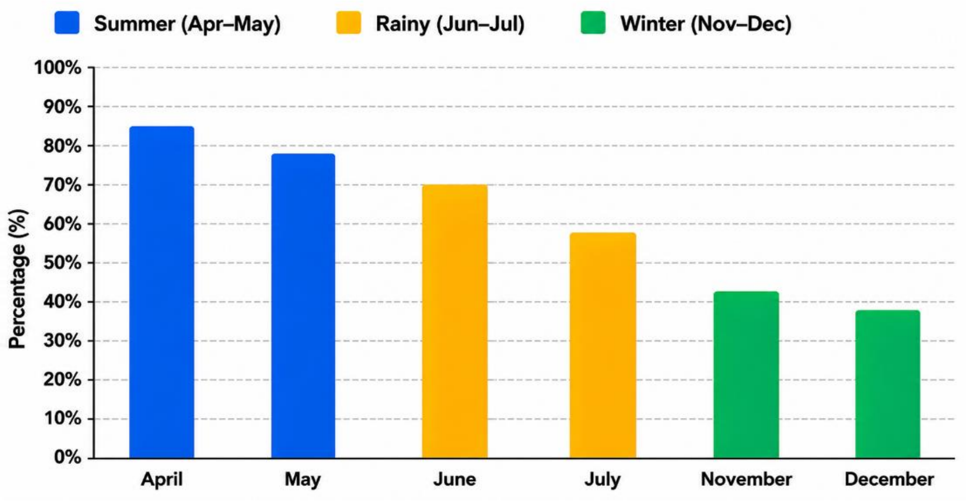

Fig 4. Wind speed variability for various seasons

Rainfall: Rainfall pattern in summer (April and May), rainy (June and July) and winter (November and December) season. Rainfall was less abundant during the summer months with April providing around 1.3 mm and May ~2.3 mm, respectively. The sparse precipitation apex is typical for the sweltering, dry summer season when it could become so hot that evaporation outstrips rain. In the rainy season (Figure 5), precipitation increased three times, with June and July being about 4.4 mm and nearly 3.9 mm; respectively. These months mark the peak of the monsoon season, when winds laden with moisture blowing off the ocean bring repeated rain, at times torrential. Precipitation in spring was modest but exceeded summer precipitation: November at 1.8 mm and December at 1.2 mm. Such type of precipitation is common with post-monsoon showers or an occasional western disturbance. The need for seasonal rainfall prediction is significant due to its implication in establishing farming cycle, the potential uses in water resources management as well as regional planning. To combine the product specification of WatchDog® 3000 Series Weather Stations —MI capability technical for hydraulic, irrigation, watershed and flood management processes modeling Spectrum Technologies, Inc. (2008).

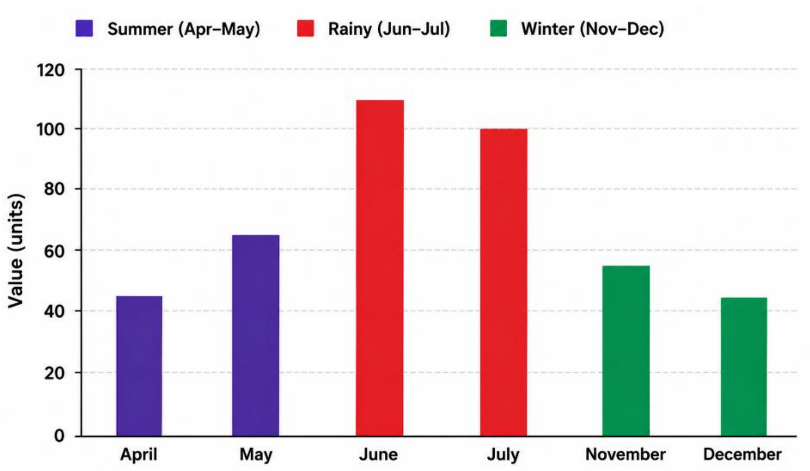

Fig 5. Rainfall variations for various seasons

5 Conclusions

The MI-AWS, with advanced sensors and wireless technologies - Bluetooth and WiFi - can aid in real-time weather monitoring and data analysis. Fulfilling this functionality requires the equipment to reliably record important environmental parameters such as temperature, humidity, wind speed and solar radiation data and hence make them especially suitable for use in sensitive areas like industrial areas and construction sites where weather events can significantly impact planning or safety [4]. The WiFi Devise (WatchDog MI-AWS) provides reliable data sharing, user-friendly mobile applications, and simple graphical displays to access current and historic weather data for improved decision making. Mobile connectivity enables scalable and low-cost data collection, while better calibration of the sensors yields quality meteorological information. Power-efficient designs allow constant and long-term monitoring, which is necessary for climate resilience building. Overall, these improved weather observation systems enhance data-driven planning and public health protection as well as disaster risk management.

The authors would like to acknowledge Institute of Aeronautical Engineering, Hyderabad for providing the facilities and support to carry out this research work.
This research did not receive any specific grant from funding agencies in the public, commercial, or non-profit sectors.
The data utilized in this research came from Automatic Weather Station via the WatchDog application.
All authors in the study helped design it. The weather information were collected from the application. Analysis of data, interpretation of results and drafting the manuscript were done by authors. All authors read and approved the final manuscript.
Conflicts of Interest: The authors declare that they have no conflicts of interest.

References

1. T.R. Oke, G. Mills, A. Christen, J.A. Voogt, Cities and global climate change, in Urban Climates (Cambridge University Press, Cambridge, 2017), pp. 360–384. https://doi.org/10.1017/9781139016476
2. Spectrum Technologies Inc., WatchDog® 3000 Series Weather Stations Product Manual (Spectrum Technologies, Aurora, IL, USA, 2022)
3. A.N. Cabrera, A. Droste, B.G. Heusinkveld, G.-J. Steeneveld, The potential of a smartphone as an urban weather station — An exploratory analysis. Front. Environ. Sci. 9, 673937 (2021). https://doi.org/10.3389/fenvs.2021.673937
4. S. Ganesan, C. P. Lean, L. Chen, K. F. Yuan, N. P. Kiat, M. R. B. Khan, IoT-enabled smart weather stations: Innovations, challenges, and future directions. Malays. J. Sci. Adv. Technol. 4, 180–190 (2024).
5. A. Chokhachian, K.K.-L. Lau, K. Perini, T. Auer, Sensing transient outdoor comfort: A georeferenced method to monitor and map microclimate. J. Build. Eng. 20, 94–104 (2018). https://doi.org/10.1016/j.jobe.2018.07.003
6. K. Lau, Y. Shi, E. Ng, Dynamic response of pedestrian thermal comfort under transient outdoor conditions. Int. J. Biometeorol. 63, 979–989 (2019). https://doi.org/10.1007/s00484-019-01712-2
7. J. Geletić, M. Lehnert, S. Savić, D. Milošević, Modelled spatiotemporal variability of outdoor thermal comfort in local climate zones of the city of Brno, Czech Republic. Sci. Total Environ. 624, 385–395 (2018). https://doi.org/10.1016/j.scitotenv.2017.12.076

8. M. Elnabawi, N. Hamza, S. Dudek, Thermal perception of outdoor urban spaces in the hot arid region of Cairo. Sustain. Cities Soc. 22, 136–145 (2016). https://doi.org/10.1016/j.scs.2016.02.005
9. L. Lovén, V. Karsisto, H. Järvinen, M. Sillanpää, T. Leppänen, E. Peltonen, et al., Mobile road weather sensor calibration by sensor fusion and linear mixed models. PLoS ONE 14, e0211702 (2019). https://doi.org/10.1371/journal.pone.0211702
10. L. Chapman, S. Bell, S. Randall, Can crowdsourcing increase the durability of an urban meteorological network? Urban Clim. 49, 101542 (2023). https://doi.org/10.1016/j.uclim.2023.101542
11. F. Barbano, E. Brattich, C. Cintolesi, A.G. Nizamani, S. Di Sabatino, M. Milelli, et al., Performance evaluation of MeteoTracker mobile sensor for outdoor applications. Atmos. Meas. Tech. 17, 3255–3278 (2024). https://doi.org/10.5194/amt-17-3255-2024