Cost-effective, High impact : the AI_r system for Air Quality Monitoring

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Air Quality Monitoring Importance

- Air quality monitoring is essential because it identifies polluted areas, tracks exposure levels, and provides reliable information about ambient air conditions.
- Traditional reference-grade stations are limited, especially in low-resource regions. Their high installation and maintenance costs mean they only cover a few locations, leaving many areas unmonitored.
- Conventional monitoring stations are **large** and require **significant space**, making them difficult to deploy widely, particularly in dense **urban environments**.

SACAQM: Developing a Cost-Effective, Scalable Air-Quality Monitoring System : AI_r

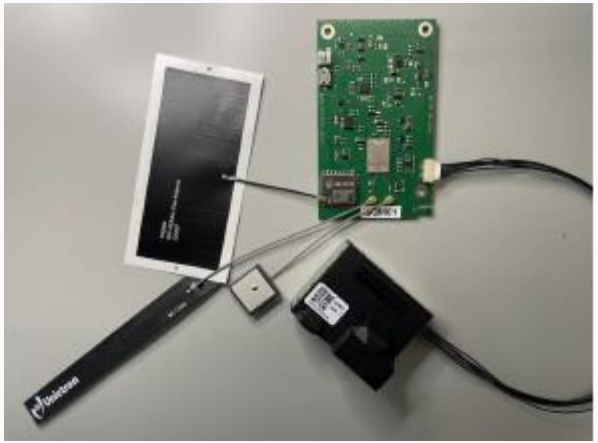
- **SACAQM** designed a cost-effective air-quality monitoring system to overcome the limitations of traditional reference-grade stations.
- The system **AI_r** integrates affordable sensors, IoT connectivity, and AI.
- Compact and easy to deploy
- The external housing protects the sensors from **weather, dust, and environmental stress**

AI_r Cost-Effective Sensor Node (external Hardware)

Designed for both indoor and outdoor environments, the system features a **UV-resistant** and **waterproof enclosure** for reliable outdoor use

The AI_r system can cover multiple locations because its sensors are easy to deploy.

AI_r Cost-Effective Sensor Node (Internal Hardware)



•The hardware includes:

- A **custom PCB** hosting the processing unit (Nordic nRF9160 SiP)
- **LTE, GPS, and LoRa antennas** for long-range communication
- A **SEN55 environmental sensor module** measuring PM, VOCs,NOx ,CO2, A-weighted decibels ,humidity, and temperature

Calibration Against a Reference-Grade Air Quality Station (SAAQIS)

- The system was calibrated against a reference-grade monitoring station (SAAQIS) to ensure measurement accuracy.

Results :

The calibration results demonstrate that the AI_r system provides accurate, consistent air-quality measurements when compared to a reference-grade station.

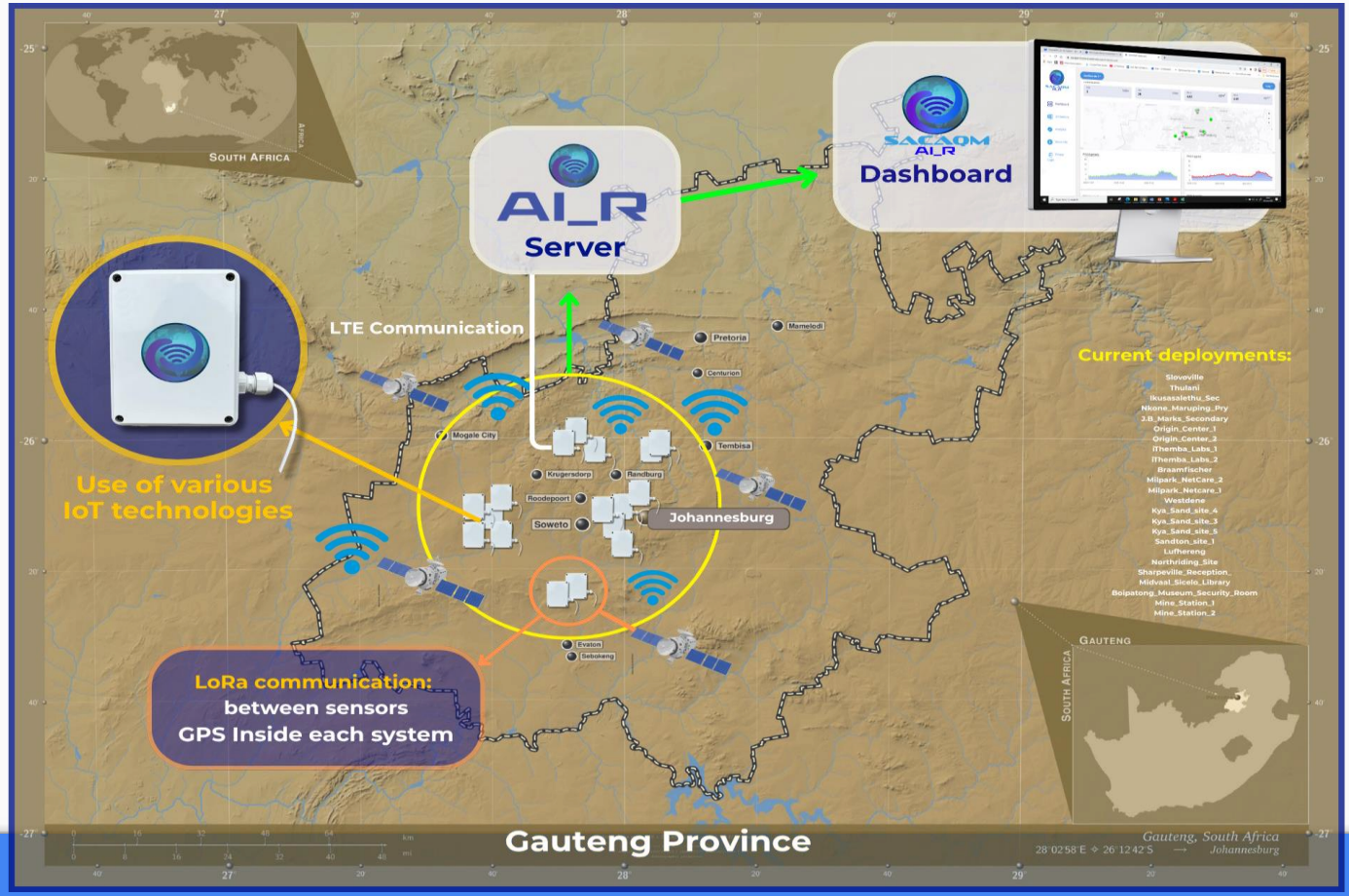
Deployment Locations and Community Engagement

Deployments take place in government buildings, including:

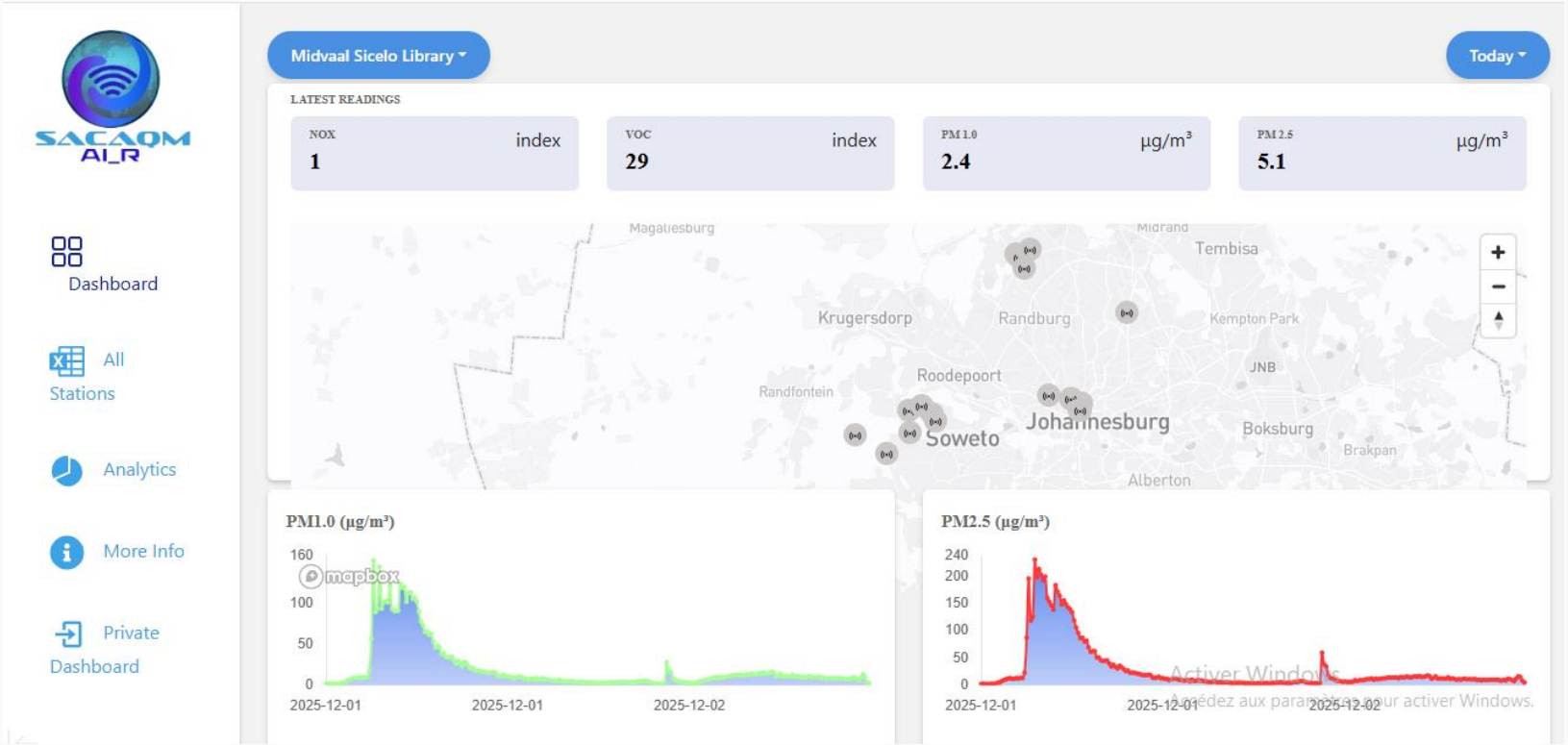
- **Clinics**
- **Hospitals**
- **Community centers**
- **Schools**

The network also extends to a growing citizen-science initiative, where we work directly with local communities to install and maintain sensors.

Overview of outdoor AI_r system across Gauteng Province



SACAQM outdoor dashboard



SACAQM AI_R

Dashboard

All Stations

Analytics

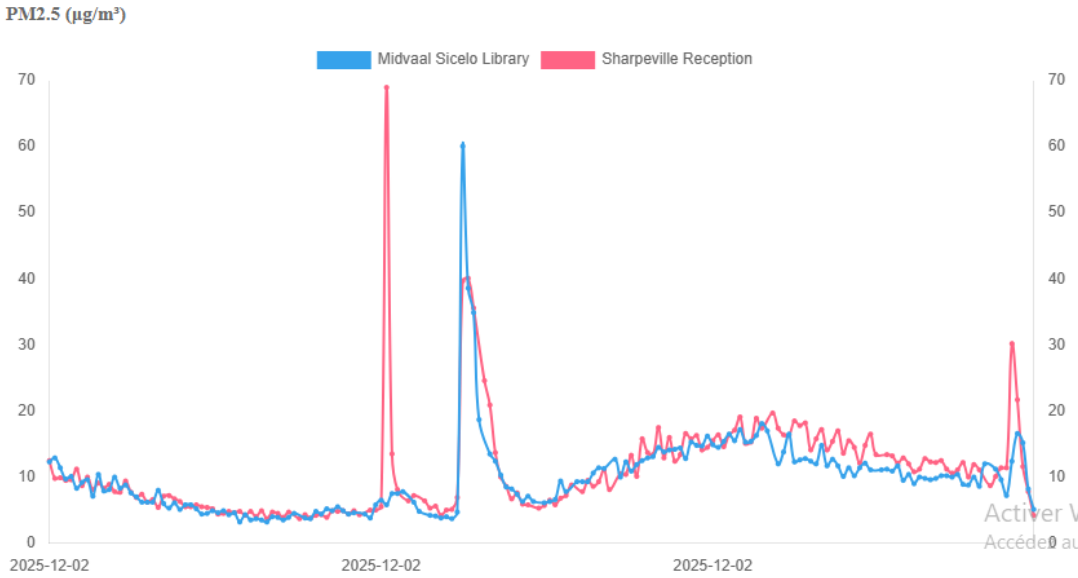
More Info

Private Dashboard

Midvaal Sicelo Library | Sharpeville Reception | Today | Raw Data

- Raw Data
- Hourly Averages
- Daily Averages
- Weekly Averages

PM2.5 (µg/m³)

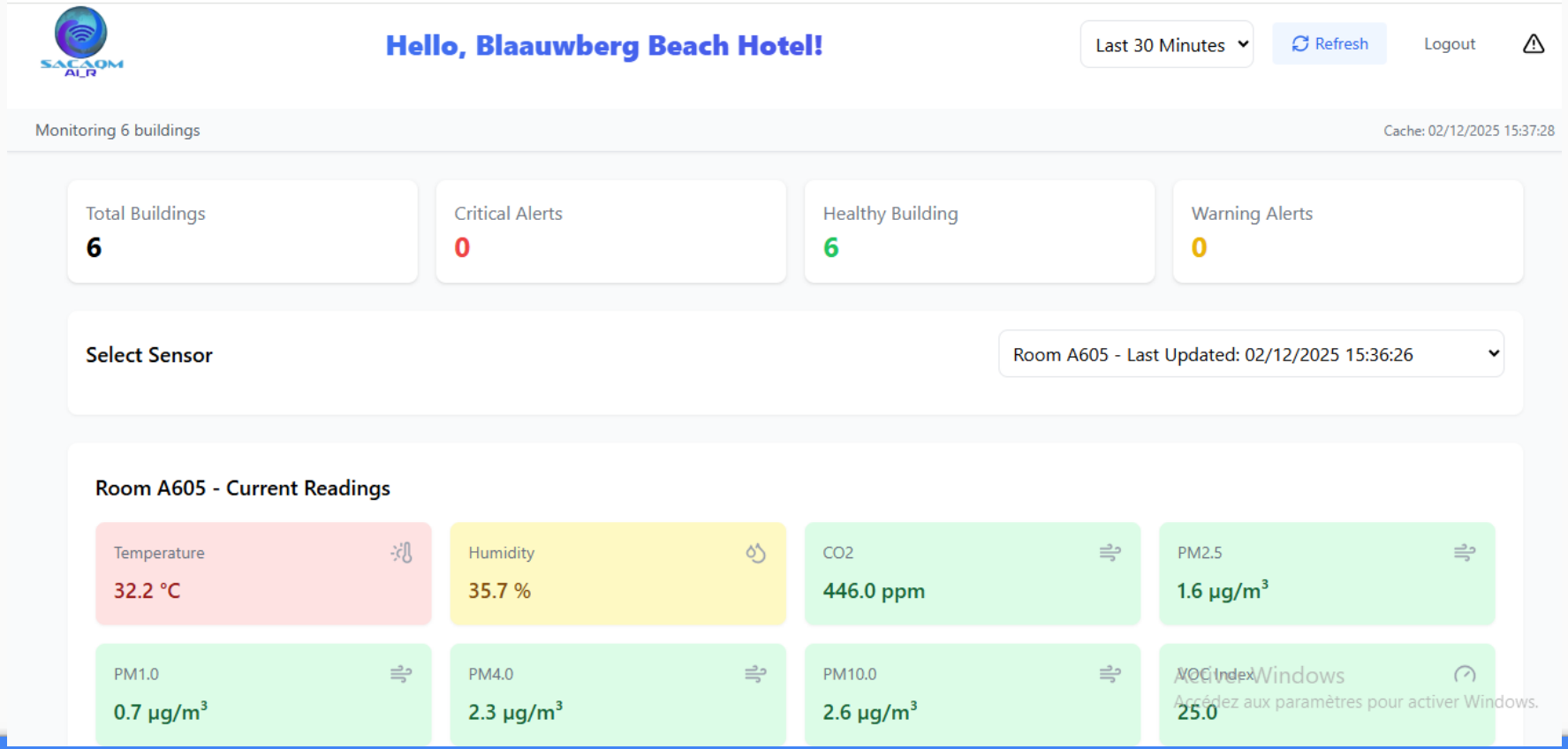


Learn more about the thresholds and air quality levels by switching your data resolution to **Daily Averages** or **Hourly Averages**.

For additional information, refer to **this link** to understand how air pollutant concentrations are categorized into levels like **Good**, **Moderate**, or **Hazardous**.

Activer Windows
Accédez aux paramètres pour activer Windows.

SACAQM indoor dashboard



Integrating AI with Cost-Effective Air Quality Sensors

- The AI_r system combines cost-effective sensor networks with **advanced Artificial Intelligence** to enhance predictive capability.

By leveraging AI, the system can:

- Identify pollution hotspots across communities
- Forecast air quality trends hours to days ahead
- Support public health decisions with real-time insight

Integrating AI with Cost-Effective Air Quality Sensors

Spatio-Temporal AI Modelling

•We developed a **spatio-temporal neural network** that integrates data from multiple AI_r cost-effective monitoring stations for **24-hour forecasting**.

•The model learns:

- **Spatial interactions** between monitoring locations
- **Temporal patterns** in pollutant behavior

SACAQM
AI_R

Data Processing

Open Meteo

15 Meteorological Variables → ANOVA Statistical Validation + Pearson Correlation → Selected 10 Meteorological Features

AI_r System → No SQL Database

$PM_{2.5}$ concentration ($\mu g/m^3$)

Data Imputation

Spacio-Temporal KNN Imputation

Outlier Detection

Neighborhood-Based outlier Detection

Sensor Data Calibrated with SAAQIS reference stations

Modelling

12 stations (4x3) Station-to-Grid Mapping

S1	S2	S3
S4	S5	S6
S7	S8	S9
S10	S11	S12

S(x) : $PM_{2.5}$ of station x + meteorological data

MinMax Normalization :

Training Spatio-temporal models: ConvTCN - ConvLSTM - ConvTransformer - ConvBILSTM

24-hour $PM_{2.5}$ Forecast Horizon: y(t+1) ... y(t+24)

Framework for Stakeholder Use and Early Warning

- The developed spatio-temporal framework has shown strong performance and reliable forecasting capability across multiple monitoring stations.

- Because of its **reliable predictions**, this framework will be considered by stakeholders—including government institutions, health agencies, and community partners—to support early-warning systems.

Thank you!