

ambee[•]

Technology & Data Guide

Cupertino, CA, USA

37.3230° N, 122.0322° W Last updated at 1340 hrs UTC on 10/28/2024

● 20 AQI

PM2.5	● 3.01 $\mu\text{g}/\text{m}^3$
PM10	● 13.84 $\mu\text{g}/\text{m}^3$
CO	● 4 ppm

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1.

Introduction

QUICK ACCESS:

[Data architecture](#) 

[Intellectual property](#) 

[Accuracy highlights](#) 

[Data security](#) 

1.1 Data architecture



Our patented AI models —

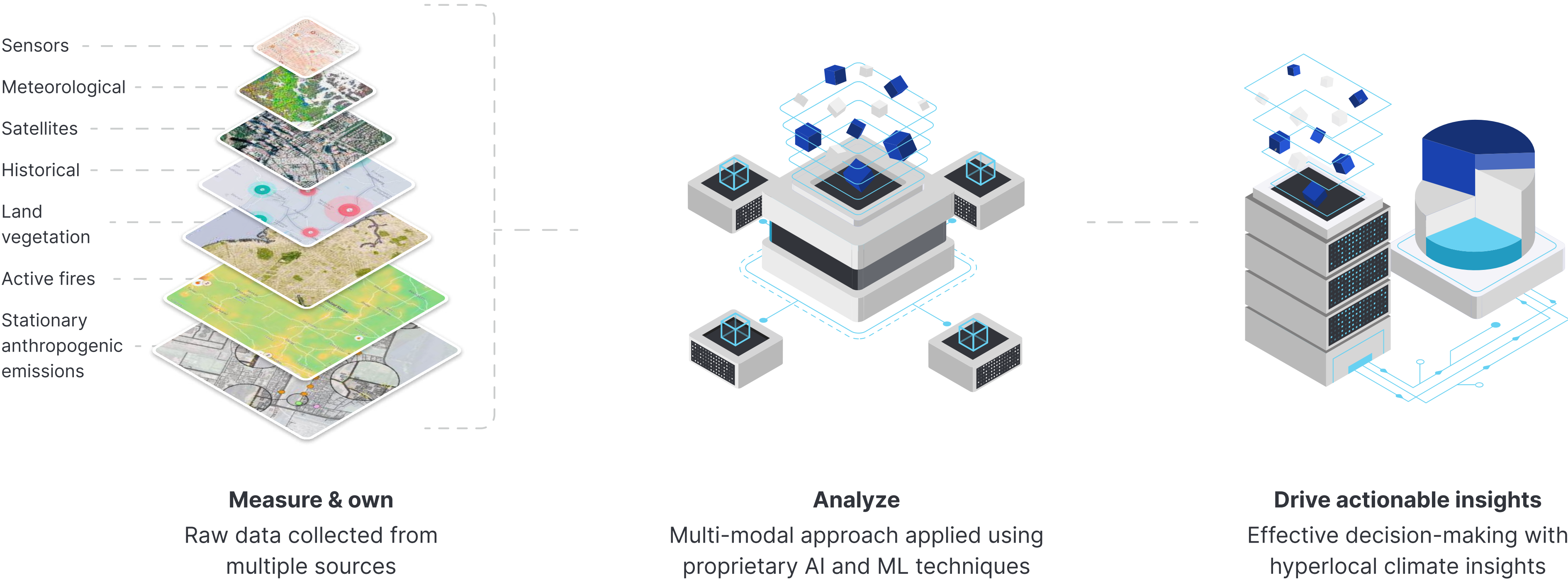


FIG. 1 | Architecture of Ambee data

1.2 Intellectual property

Our superior accuracy is a result of patented systems ensuring our climate models are ahead of the curve, incorporating the latest advances in AI and ML.

3

Patents filed

- 2

Air quality
- 1

Pollen



1. WO2022195628 - AN ARTIFICIAL NEURAL NETWORK BASED VIRTUAL AIR MONITORING NETWORK SYSTEM

Artificial neural network to monitor air quality by creating a virtual network of stations and sensors to gather air quality information.

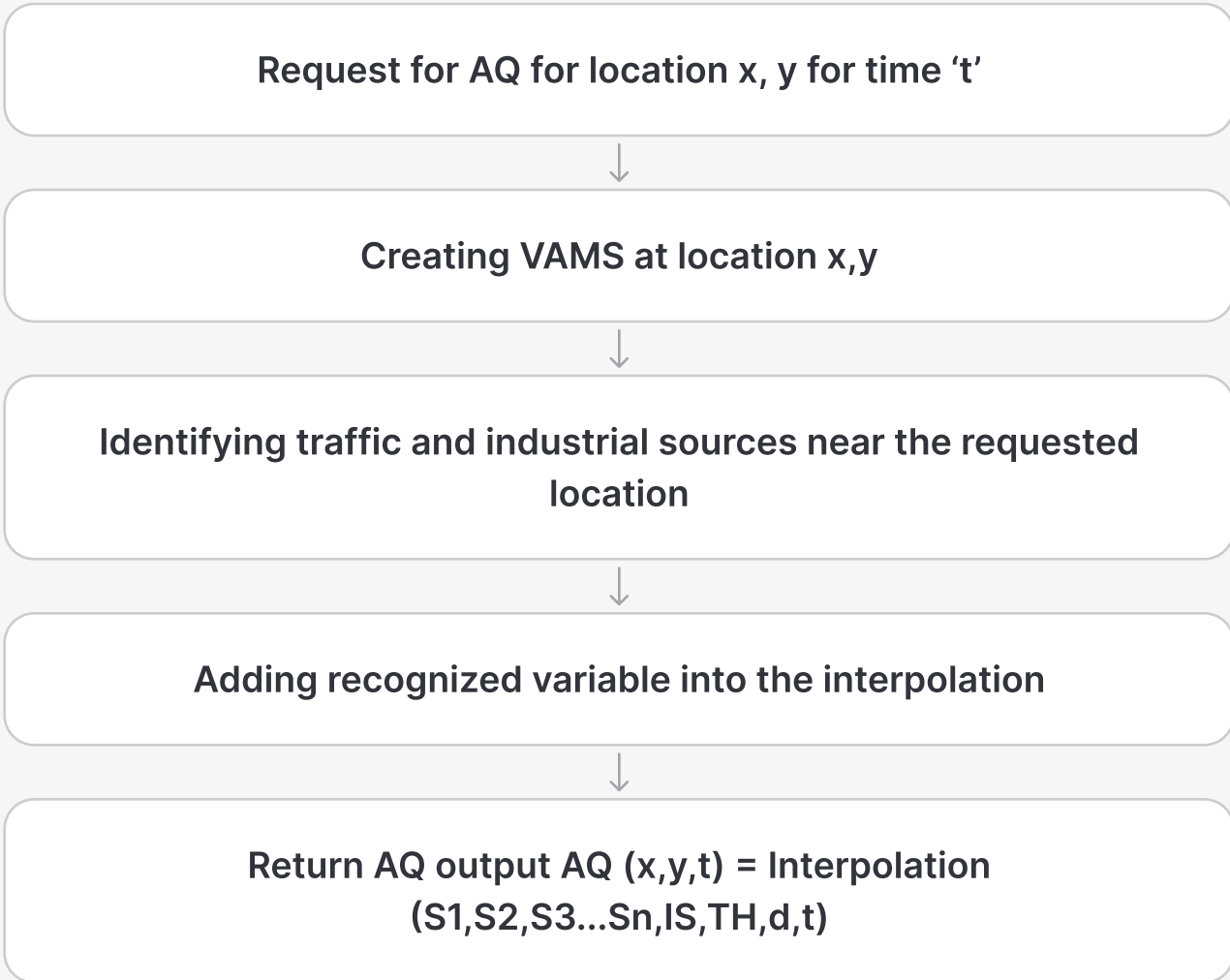


EXHIBIT 1 | Functional overview of the patent

2. SYSTEMS AND METHODS FOR A MULTIMODAL SPATIO-TEMPORAL AIR QUALITY NETWORK (PROVISIONAL)

A comprehensive air quality monitoring network that combines sensor data, satellite imagery, geospatial, and demographic information with machine learning techniques.

3. SYSTEMS AND METHODS FOR WEATHER-BASED POLLEN MONITORING (PROVISIONAL)

A system for precise pollen count predictions across regions and times, utilizing environmental and seasonal data with machine learning. It incorporates phenological inputs and plant peak, start, and end seasons to improve accuracy.

1.3 Accuracy highlights

- Integrity of reference-grade sensor data is maintained.
- Scientific anomalies and errors in reference-grade sensors are effectively managed.
- Missing values are thoroughly handled where stations are offline.
- AI-based algorithms enable precise data interpolation within a **10 km** radius.
- AI-based calibration enhances satellite data accuracy within a **50 km** proximity.



Weighted **anthropogenic** data



Feature-engineered data



10+ years of training data



Multiple algorithms in ETL



Unique models for different geographies

1.4 Data security



Ambee’s cloud infrastructure safeguards data with top industry security standards, backed by SOC 2 Type II and ISO27001 certifications for enterprise-grade protection.



SOC 2 Type II



ISO 27001

EXHIBIT 2 | Ambee’s infosec credentials



Continuous monitoring

Our data infrastructure is continuously monitored for compliance with SOC2 Type II and ISO 27001 requirements.



Reliable uptime

Our fault-tolerant infrastructure ensures availability even during extreme demand.



2.

Ambee air quality

QUICK ACCESS:

[Dataset overview](#) 

[Air quality live](#) 

[Air quality forecast](#) 

2.1



Dataset overview

Ambee’s air quality dataset

Comprehensive pollution parameters

PARAMETER	DESCRIPTION
PM2.5	Particulate matter < 2.5 µm (µg/m³)
PM10	Particulate matter < 10 µm (µg/m³)
SO2	Sulphur dioxide (ppb)
NO2	Nitrogen dioxide (ppb)
O3	Ozone (ppb)
CO	Carbon monoxide (ppm)
AQI	Air quality index
updatedAt	ISO timestamp of event (UTC)
aqiInfo	Brief info about the effects of the AQI

TABLE 1 | Response parameters of Ambee's AQ API



Data specifications



Multiple AQ indices
Including the US EPA AQI, DAQI (UK), NAQI (India, CPCB), and other national indices available upon request



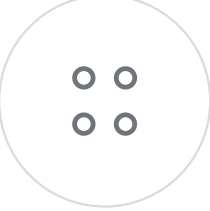
Global
Coverage



10+ years
Hourly historical



96 hrs*
Forecast



< 1 km²*
Granularity

*Available on demand

2.2



Air quality live

QUICK ACCESS:

[Validation methodology](#) 

[Accuracy comparison](#) 

Validation methodology

Our approach: Leave-one-out cross-validation (LOO-CV)

Ambee employs the “leave one out”¹ method to ensure the accuracy of our AQ models. Here’s how it works:

- We start by "leaving out" one sensor from our dataset.
- The machine learning model is trained on the remaining sensor data, excluding the selected sensor.
- Once trained, the model predicts the air quality for the location of the sensor that was left out.
- The predicted air quality value is compared with the actual value recorded by the sensor.
- This process is repeated for every sensor in the dataset, with each sensor being left out once.

By evaluating the model’s performance across all sensor locations, we can assess how well the model generalizes to new, unseen areas. This allows us to estimate the accuracy of predictions, even for regions where no sensors are installed.

There are some caveats to keep in mind, that might affect the accuracy of air quality models in general, and these are:

- Limited reference-grade sensors in some regions may reduce prediction accuracy, especially in areas with sparse sensor networks.
- Different sensors can report varying PM2.5 levels due to differences in calibration and sensitivity.
- Air quality sensors may experience delays in updating their data or might revise data after they have already been published. This might affect the accuracy of the models.

[1] - Webb, G. I., Sammut, C., Perlich, C., Horváth, T., Wrobel, S., Korb, K. B., ... Raedt, L. D. (2011). Leave-One-Out Cross-Validation. Encyclopedia of Machine Learning, 600-601. doi:10.1007/978-0-387-30164-8_469

Sammut, C. and Webb, G.I. (2010b) 'Leave-One-Out Cross-Validation,' in Springer eBooks, pp. 600–601. https://doi.org/10.1007/978-0-387-30164-8_469



Accuracy comparison

Ambee’s air quality data outperforms Google’s with unmatched accuracy.

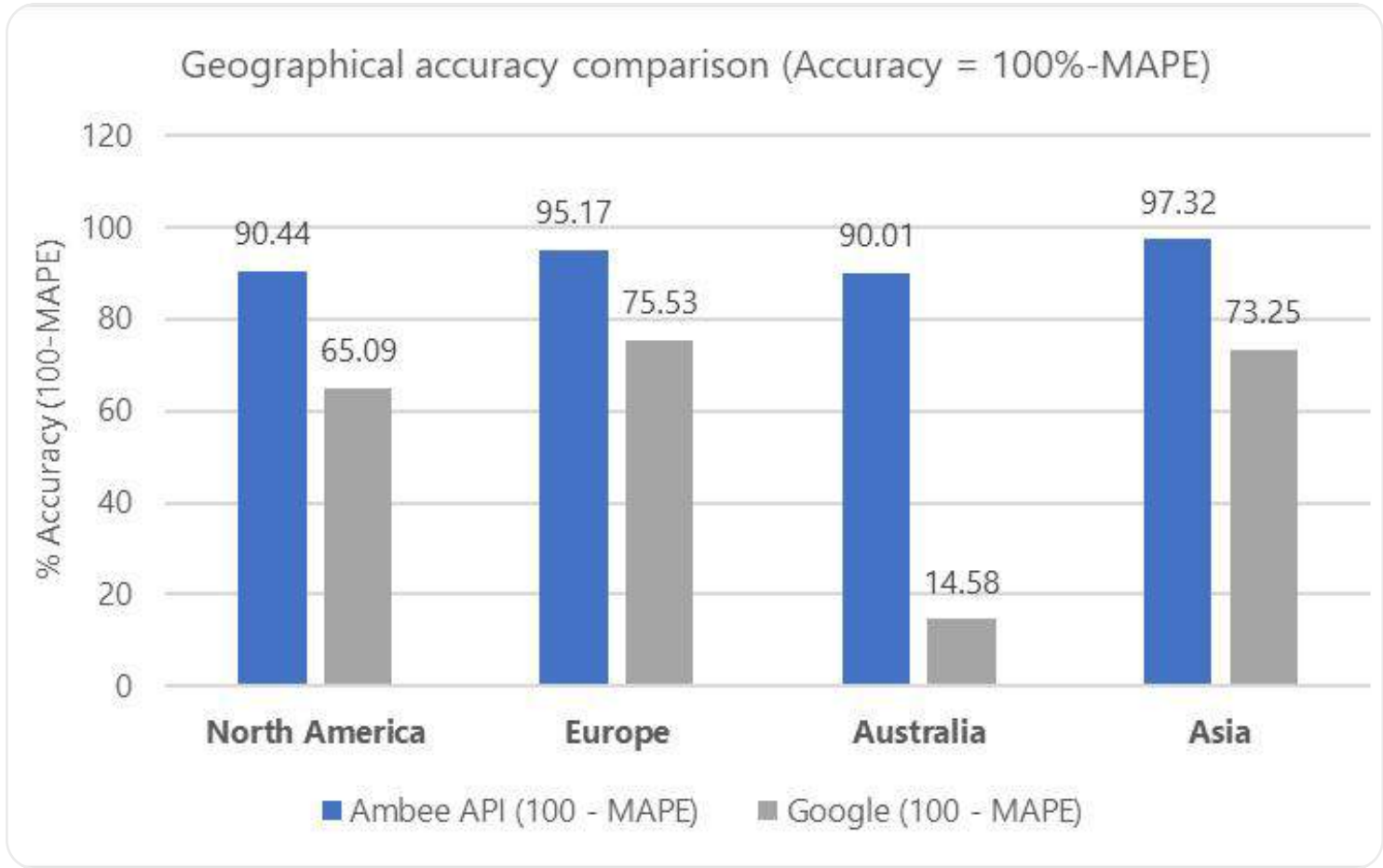


EXHIBIT 3 | Accuracy % (100-MAPE) comparison with Google

CONTINENTS	AMBEE ACCURACY % (100 - MAPE)	GOOGLE ACCURACY % (100 - MAPE)
North America	90.44	65.09
Europe	95.17	75.53
Australia	90.01	14.58
Asia	97.32	73.25

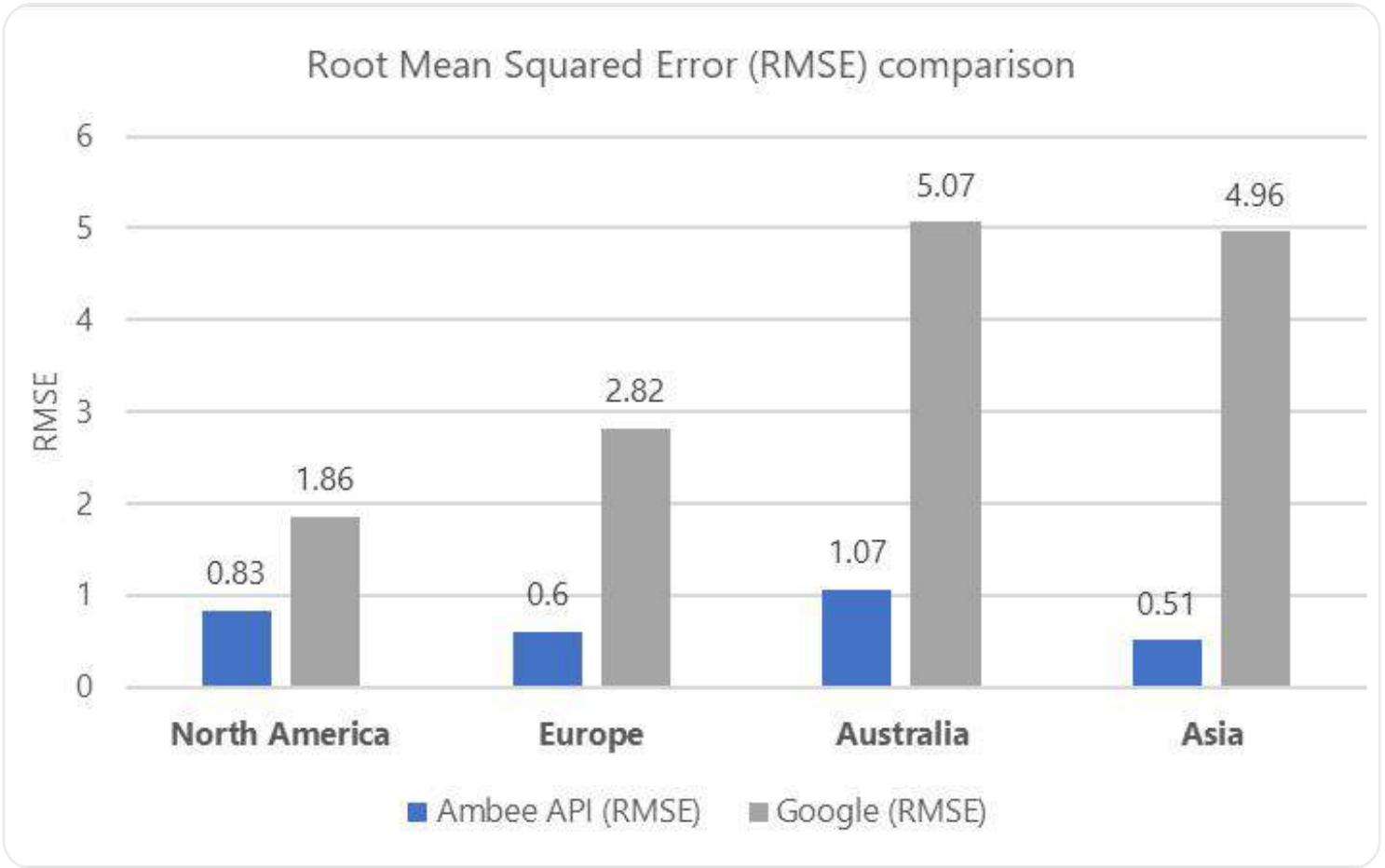


EXHIBIT 4 | Root mean squared error (RMSE) comparison with Google

CONTINENTS	AMBEE RMSE (µg/m3)	GOOGLE RMSE (µg/m3)
North America	0.83	1.86
Europe	0.6	2.82
Australia	1.07	5.07
Asia	0.51	4.96

- Ambee’s data consistently outperformed Google across different geographies, showing a higher accuracy and lower RMSE.
- Ambee’s RMSE is significantly and consistently lower across regions, significantly better than the 7 µg/m³ limit of maximum permissible of RMSE set by the USEPA for PM2.5

Terminology

MAPE (mean absolute percentage error): Measures the average of absolute percentage errors between predicted and actual values.

RMSE (root mean squared error): Measures the average magnitude of error in a set of predictions by calculating the square root of the average of squared differences between predicted and actual values.

Accuracy comparison (contd.)



Ambee’s accuracy benchmark

The USEPA sets a maximum permissible root mean squared error (RMSE) of [7 µg/m³ for PM2.5](#) over a 24-hour period. We have set an even higher internal standard, aiming for half ($\pm 3.5 \mu\text{g}/\text{m}^3$) of that value to ensure that our AQ data meets stringent accuracy levels.

The following graphs display trend lines of PM2.5 levels over a 48-hour period from 2nd to 4th September 2024 for several stations across different regions of the world. PM2.5 was chosen for these comparisons since it is the most commonly measured pollutant at many stations. Additionally, PM2.5 is often the most prevalent pollutant in many areas, making it a key indicator of air quality and a priority for monitoring.

Performance metrics

Next to each model in the legend, you will find these performance metrics:

- **MAE (mean absolute error):** Measures the average magnitude of errors between the predicted and actual values.
- **RMSE (root mean squared error):** Measures the average magnitude of error in a set of predictions by calculating the square root of the average of squared differences between predicted and actual values.

LEGEND	DESCRIPTION
X-axis (timestamp)	Represents the time period from Sep 2nd to Sep 4th, 2024
Y-axis (PM2.5)	Indicates the concentration of PM2.5 in micrograms per cubic meter (µg/m³)
Solid black line (station) —	Represents the actual air quality readings from a reference-grade station. This serves as the "ground truth" or benchmark against which predictions from various models are compared.
Dashed blue line (Ambee model/ algorithm) - - -	Data from Ambee’s model/algorithm using the leave-one-out method. This serves as an accuracy estimate for areas without sensors.
Dashed teal line (Google) - - -	Data from Google’s API, potentially modified by their algorithm in certain locations, based on sensor data.
Dashed yellow line (Ambee API) - - -	Data from Ambee’s AQ API, where sensor data may be adjusted by our algorithm to account for anomalies or outliers.
Shaded blue area (error range) [shaded box]	Represents a $\pm 3.5 \mu\text{g}/\text{m}^3$ deviation range from the actual station data. This region gives a visual idea of how close each model is to the station data.

TABLE 2 | Legend guide for Ambee’s live AQ comparison graphs

Comparing Ambee’s live AQ v. Google: USA - Los Angeles, California LIVE



[See more in appendix](#)

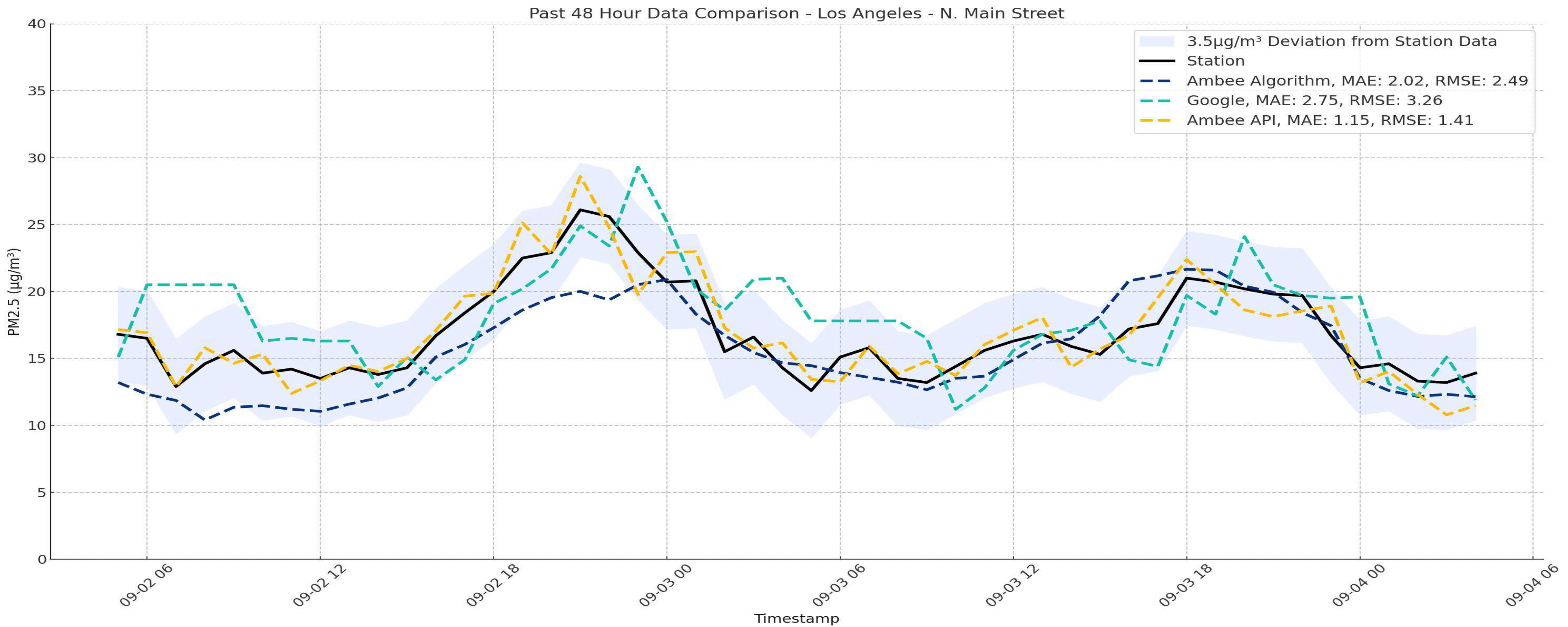


EXHIBIT 5 | Accuracy comparison between Ambee's live AQ and Google in Los Angeles from 2nd to 4th September 2024

Comparing Ambee’s live AQ v. Google: EUR – Paris, France LIVE



[See more in appendix](#)

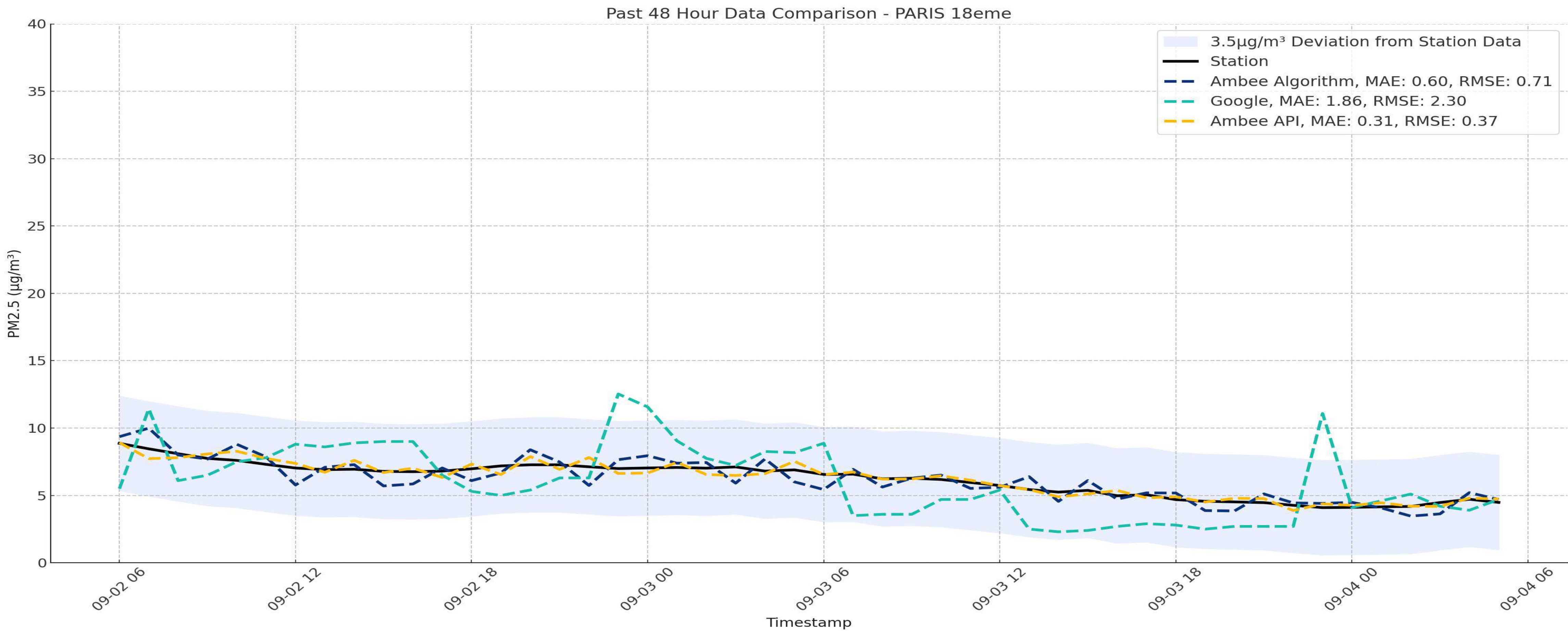


EXHIBIT 6 | Accuracy comparison between Ambee's live AQ and Google in Paris from 2nd to 4th September 2024

Comparing Ambee’s live AQ v. Google: AUS - Melbourne, Victoria LIVE



[See more in appendix](#)

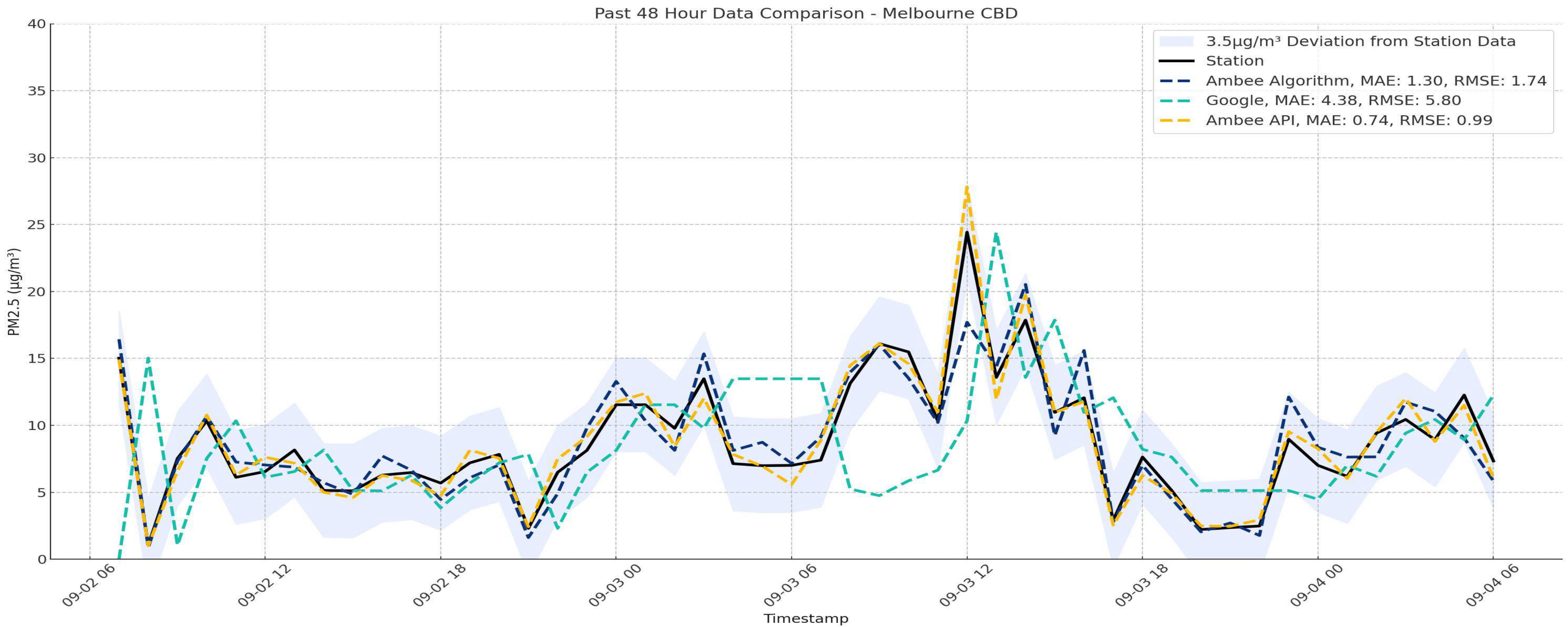


EXHIBIT 7 | Accuracy comparison between Ambee's live AQ and Google in Melbourne from 2nd to 4th September 2024

Comparing Ambee’s live AQ v. Google: ASIA – Osaka, Japan LIVE



[See more in appendix](#)

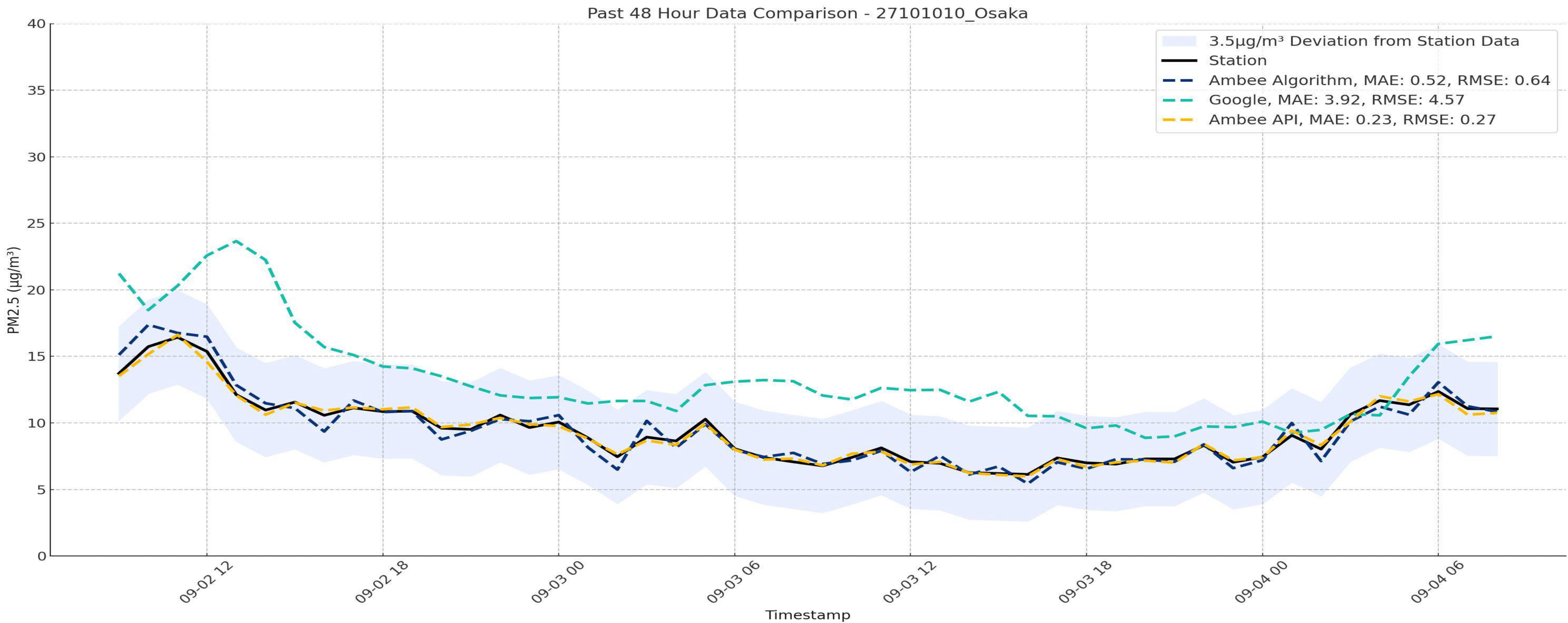


EXHIBIT 8 | Accuracy comparison between Ambee's live AQ and Google in Osaka from 2nd to 4th September 2024

Air quality forecast

QUICK ACCESS:

[Validation methodology](#) 

[Accuracy comparison](#) 

Validation methodology

Our approach: Post-forecast observation

We generated a 48-hour forecast from 2nd to 4th September 2024 using our predictive models. After the forecast period, we gathered real-time observational data from ground stations, enabling a direct comparison between the predicted values and the actual observations. This comparison assessed the accuracy of our predictions and validated the performance of our forecasting model during the specified timeframe.

Accuracy comparison



Performance metrics

Next to each model in the legend, you will find these performance metrics:

- **MAE (mean absolute error):** Measures the average magnitude of errors between the predicted and actual values.
- **RMSE (root mean squared error):** Measures the average magnitude of error in a set of predictions by calculating the square root of the average of squared differences between predicted and actual values.

LEGEND	DESCRIPTION
X-axis (timestamp)	Represents the time period from Sep 2nd to Sep 4th, 2024
Y-axis (PM2.5)	Indicates the concentration of PM2.5 in micrograms per cubic meter (µg/m³)
Black line (station) —	Represents the actual air quality readings from a reference-grade station. This serves as the "ground truth" or benchmark against which predictions from various models are compared.
Dashed yellow line (Ambee API) - - -	Predictions from Ambee's AQ API, where sensor data may be adjusted by our algorithm to account for anomalies or outliers.
Shaded blue area 	Represents a ±3.5 µg/m³ deviation range from the actual station data. This region gives a visual idea of how close each model is to the station data.

TABLE 3 | Legend guide for Ambee's forecast AQ comparison graphs

Benchmarking Ambee’s AQ forecast v. ground station: USA - Austin, Texas

FORECAST



See more in appendix

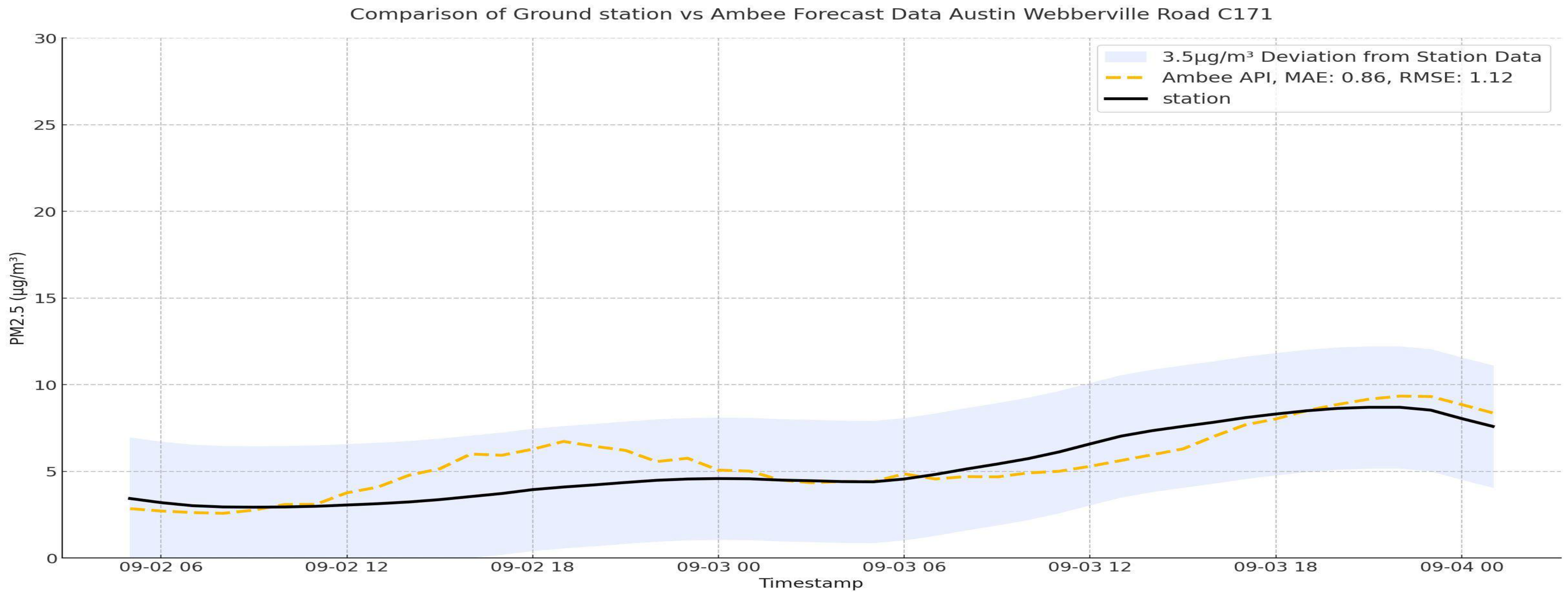


EXHIBIT 9 | Ambee forecast AQ v. ground station in Austin from 2nd to 4th September 2024

Benchmarking Ambee’s AQ forecast v. ground station: EUR – Vitry-sur-Seine, France

FORECAST



See more in appendix

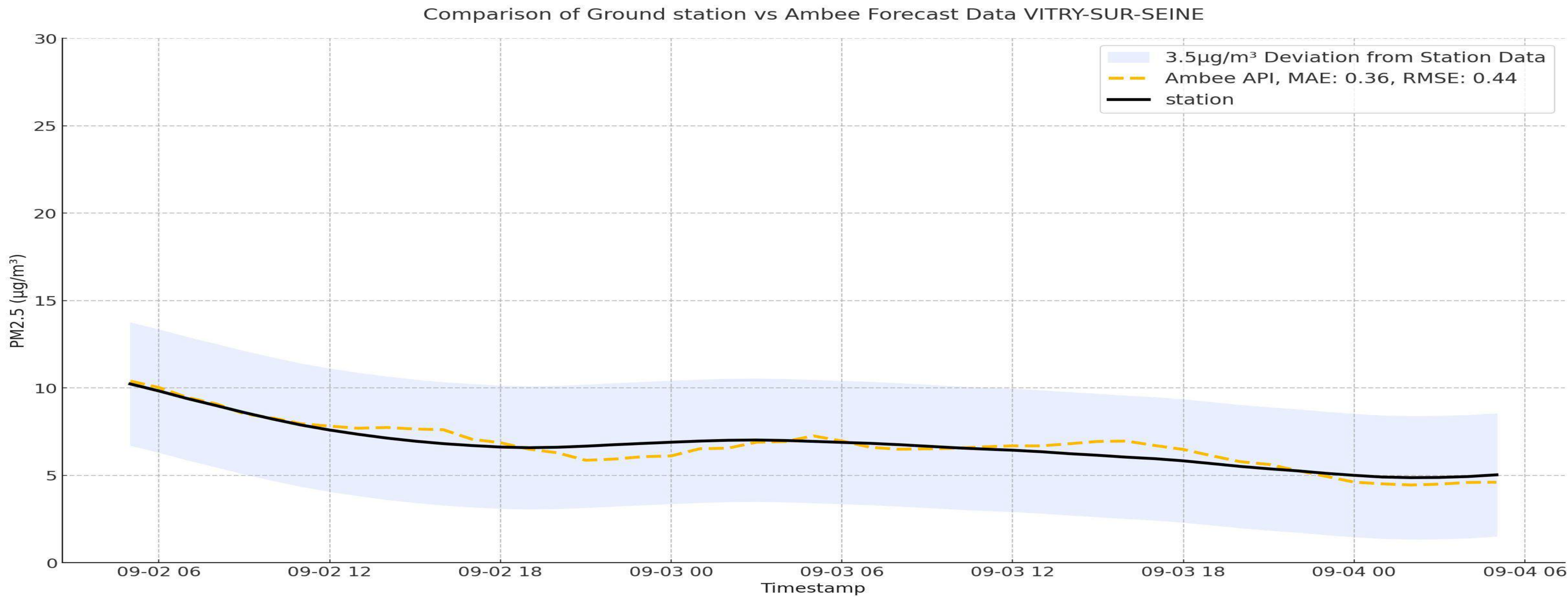


EXHIBIT 10 | Ambee forecast AQ v ground station in Vitry-sur-Seine from 2nd to 4th September 2024

Benchmarking Ambee’s AQ forecast v. ground station: AUS – Targinnie, Queensland

FORECAST



See more in appendix

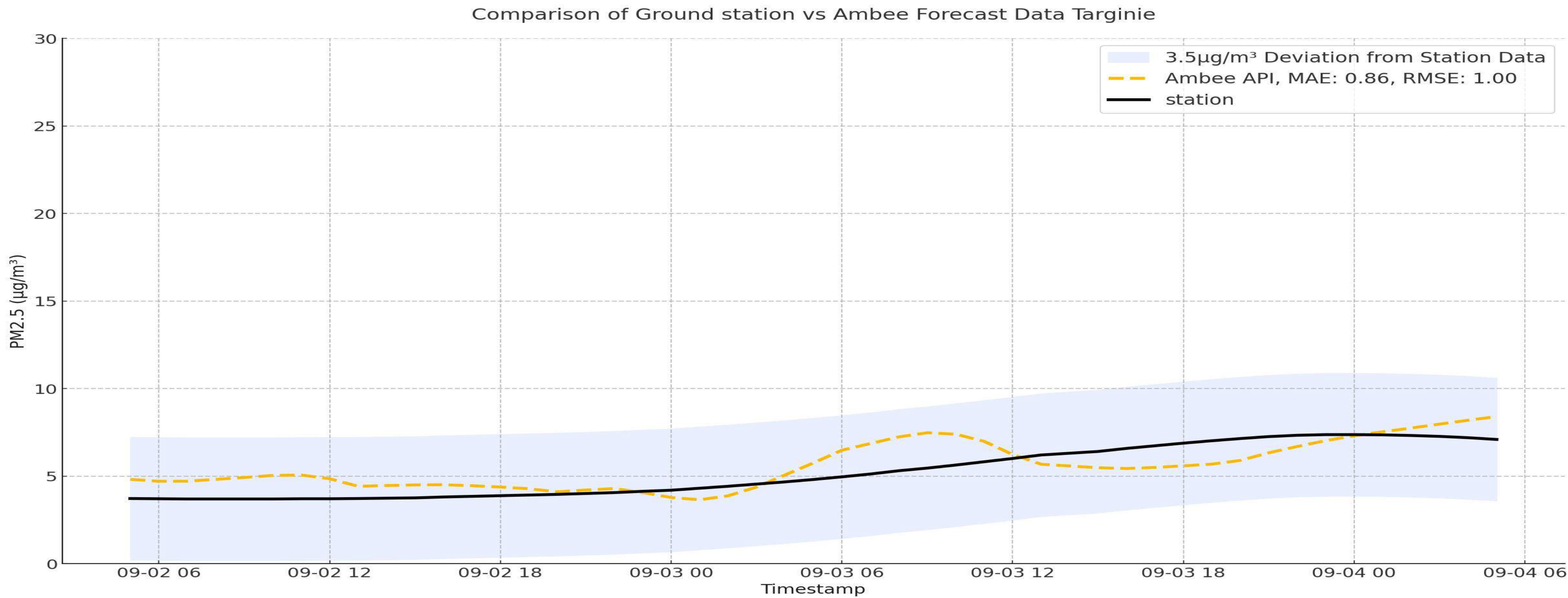


EXHIBIT 11 | Ambee forecast AQ v ground station in Targinnie from 2nd to 4th September 2024

5. Appendix



QUICK ACCESS:

[Additional air quality accuracy comparisons](#) 



Additional air quality accuracy comparisons

LIVE

Rahway, New Jersey

Paterson, New Jersey

Chicago, Illinois

Kingery, Illinois

Northbrook, Illinois

Glendale, California

Houston, Texas

Paris, France

Berlin, Germany

Brussels, Belgium

Madrid, Spain

Cammeray, New South Wales

Spotswood, Victoria

Randwick, New South Wales

New Delhi, India

Bangalore, India

Mumbai, India

Tokyo, Japan

FORECAST

Alamo Lake, Arizona

Chehalis, Washington

Kungsgatan, Sweden

Eriksgatan, Sweden

Hornsgatan, Sweden

Aylesford, England

St Albans, England

Aberdeen, Scotland

Cairns, Queensland

Kalgoorlie, Western Australia

Comparing Ambee's live AQ v. Google: USA - [Rahway, New Jersey](#) LIVE

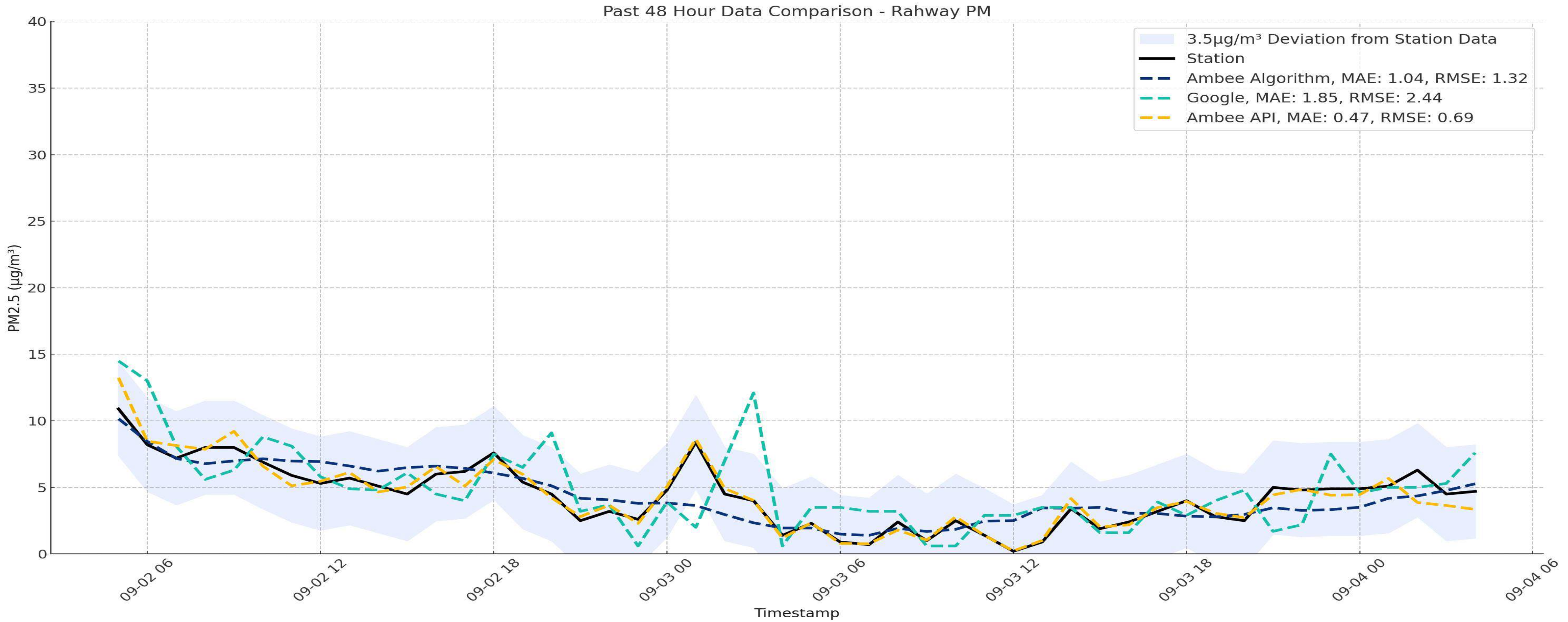


EXHIBIT 12 | Accuracy comparison between Ambee's live AQ and Google in Rahway from 2nd to 4th September 2024

Comparing Ambee's live AQ v. Google: USA - Paterson, New Jersey LIVE

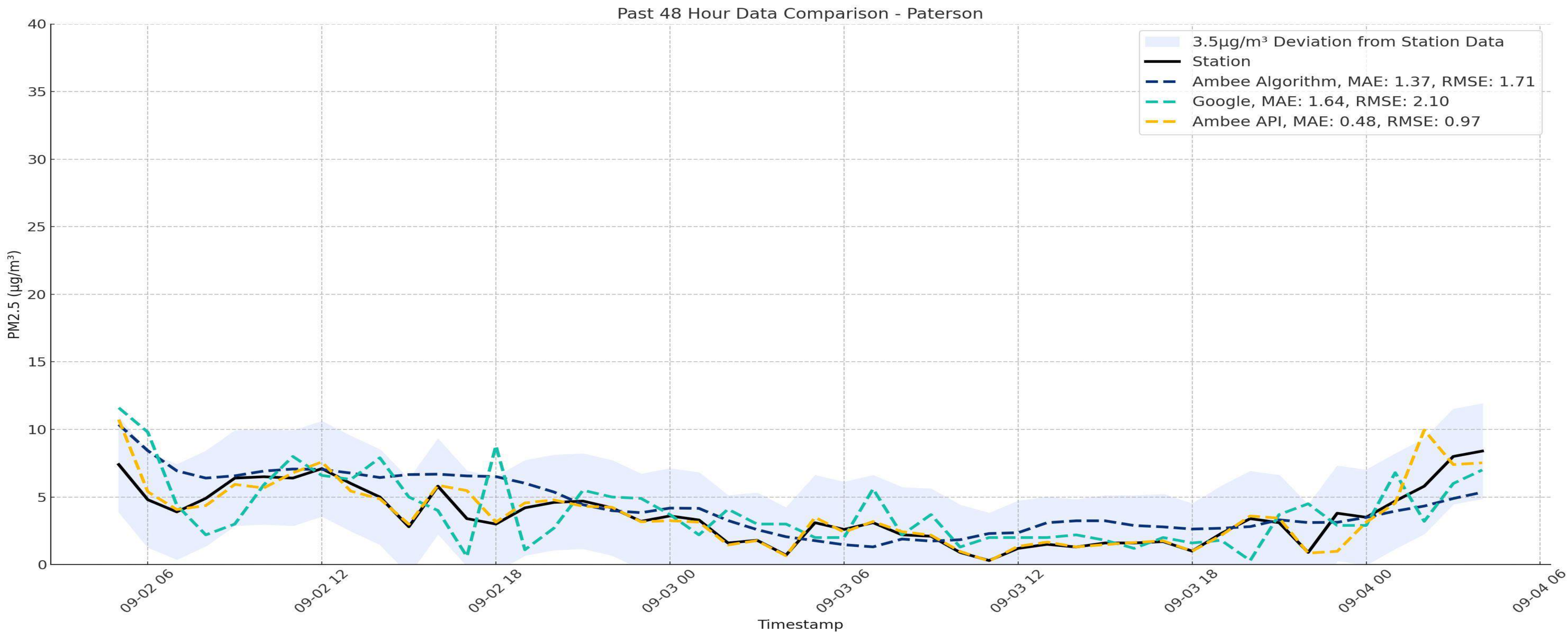


EXHIBIT 13 | Accuracy comparison between Ambee's live AQ and Google in Paterson from 2nd to 4th September 2024

Comparing Ambee's live AQ v. Google: USA - Chicago, Illinois LIVE

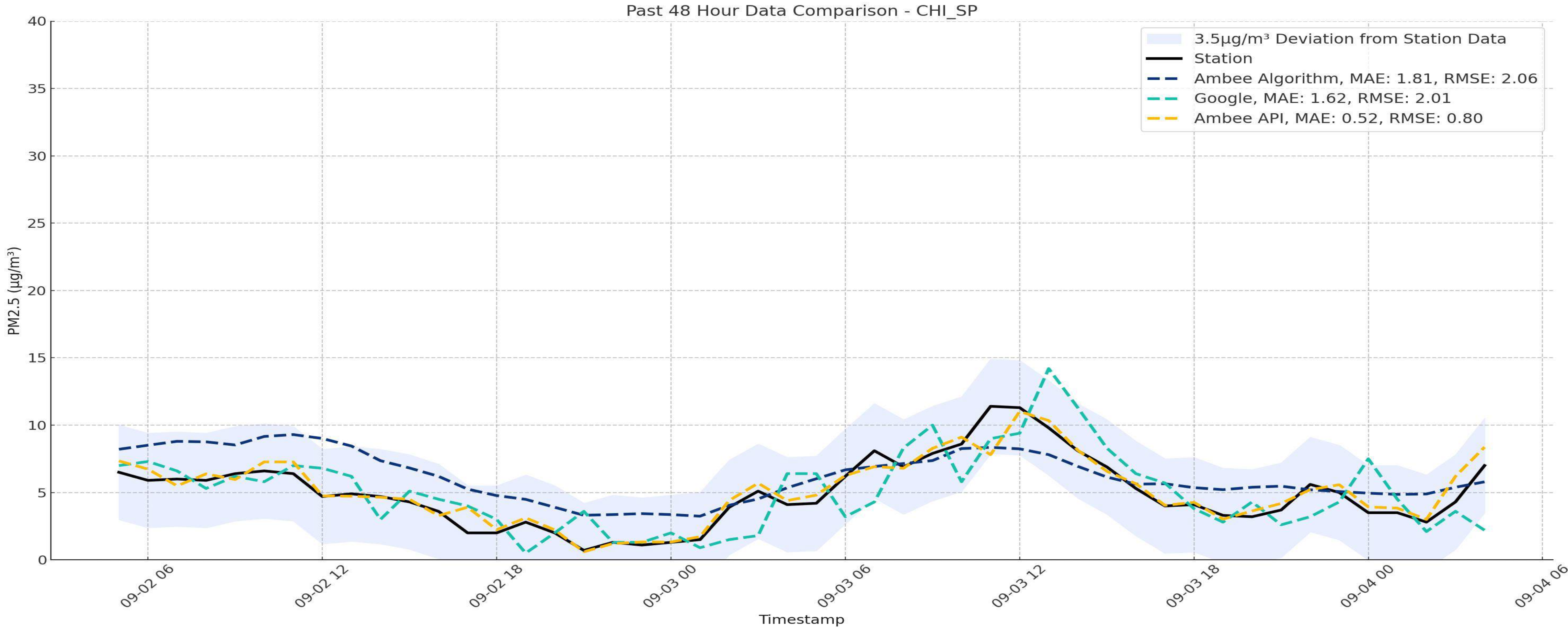


EXHIBIT 14 | Accuracy comparison between Ambee's live AQ and Google in Chicago from 2nd to 4th September 2024

Comparing Ambee’s live AQ v. Google: USA - Kingery, Illinois LIVE

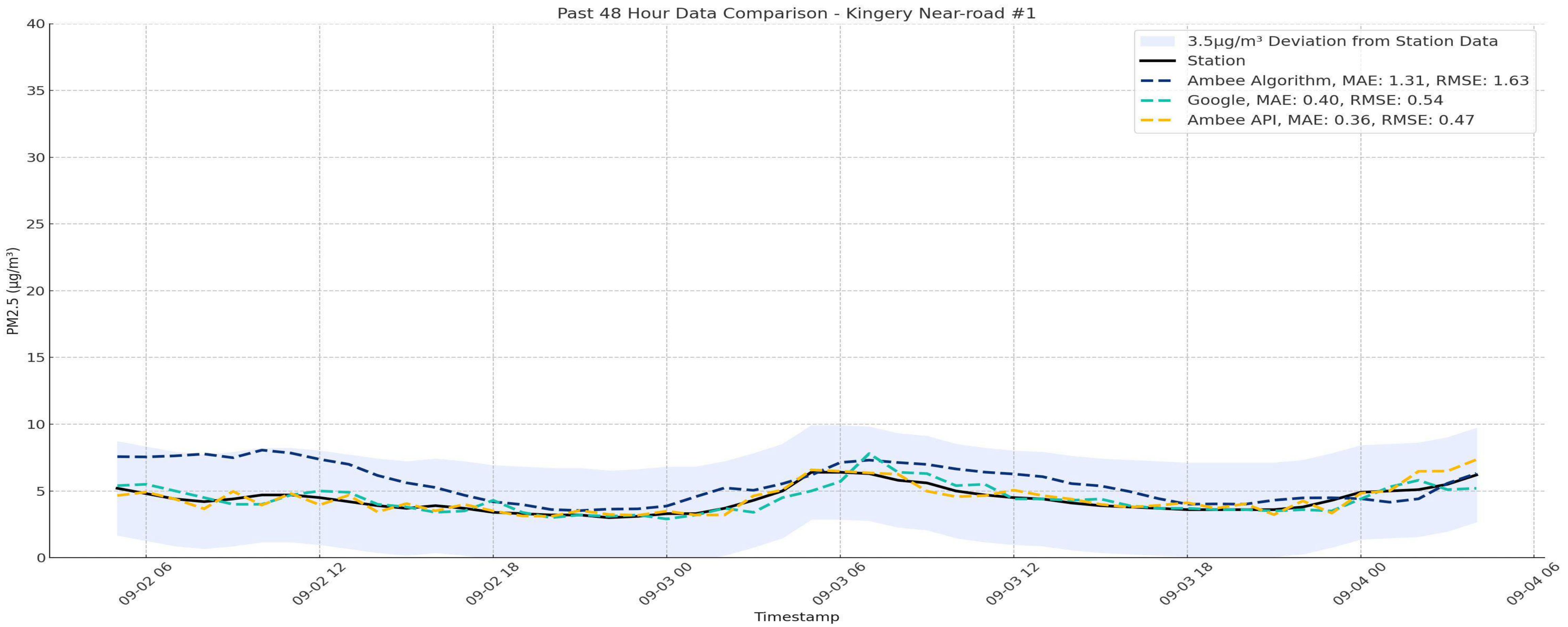


EXHIBIT 15 | Accuracy comparison between Ambee's live AQ and Google in Kingery from 2nd to 4th September 2024

Comparing Ambee's live AQ v. Google: USA - Northbrook, Illinois LIVE

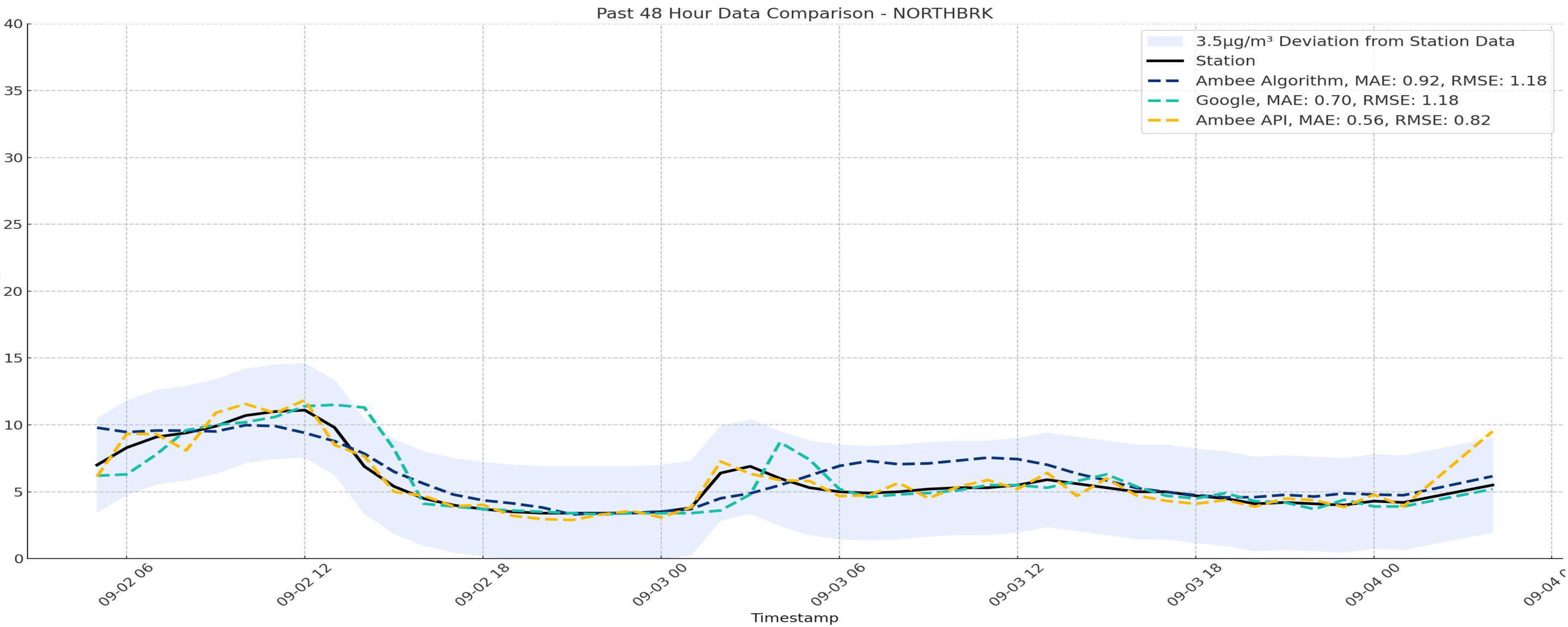


EXHIBIT 16 | Accuracy comparison between Ambee's live AQ and Google in Northbrook from 2nd to 4th September 2024

Comparing Ambee's live AQ v. Google: USA - Glendale, California LIVE

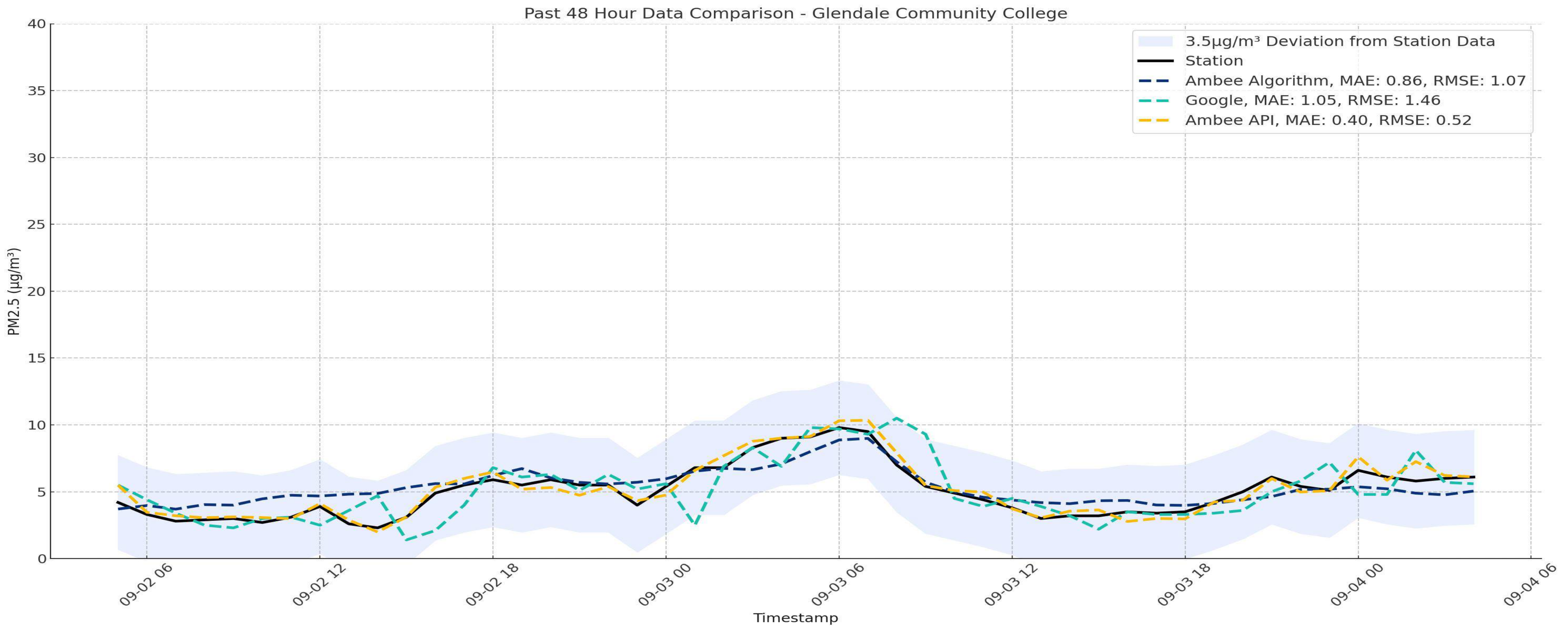


EXHIBIT 17 | Accuracy comparison between Ambee's live AQ and Google in Glendale from 2nd to 4th September 2024

Comparing Ambee's live AQ v. Google: USA - Houston, Texas LIVE

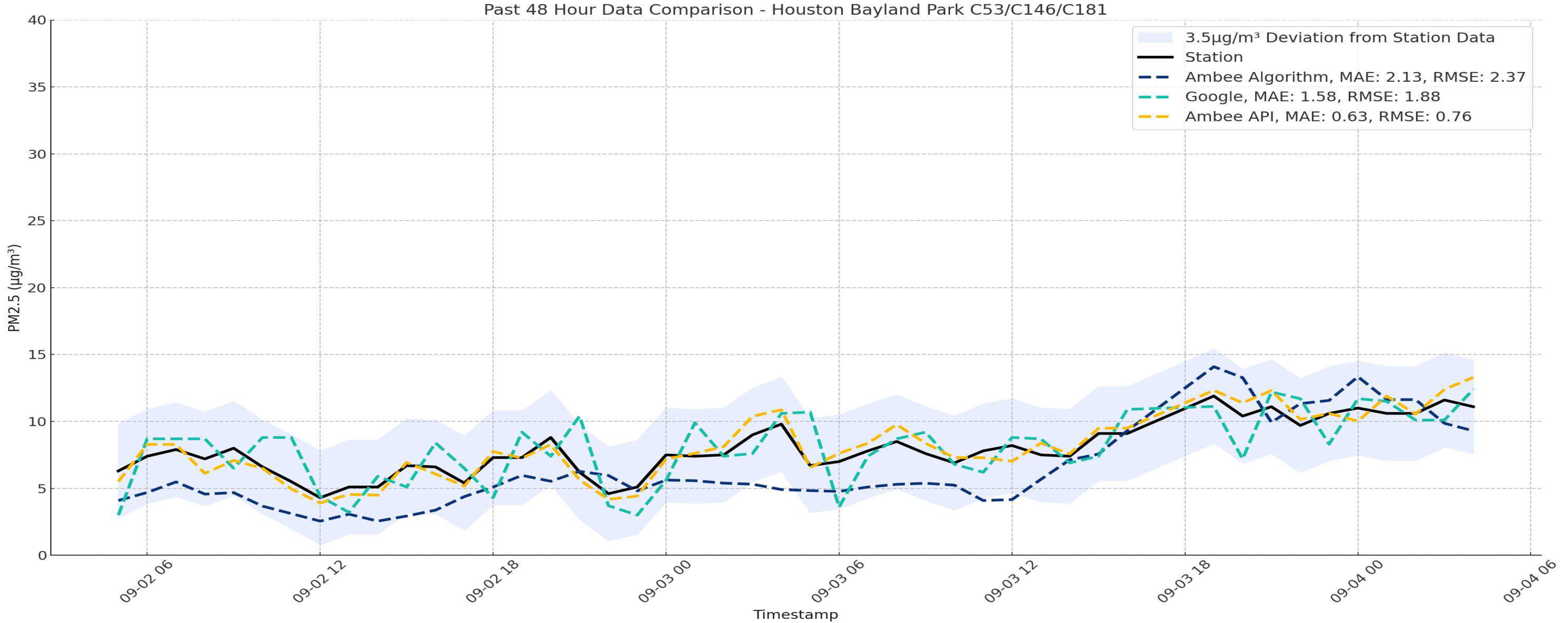


EXHIBIT 18 | Accuracy comparison between Ambee's live AQ and Google in Houston from 2nd to 4th September 2024

Comparing Ambee’s live AQ v. Google: EUR – Paris, France LIVE

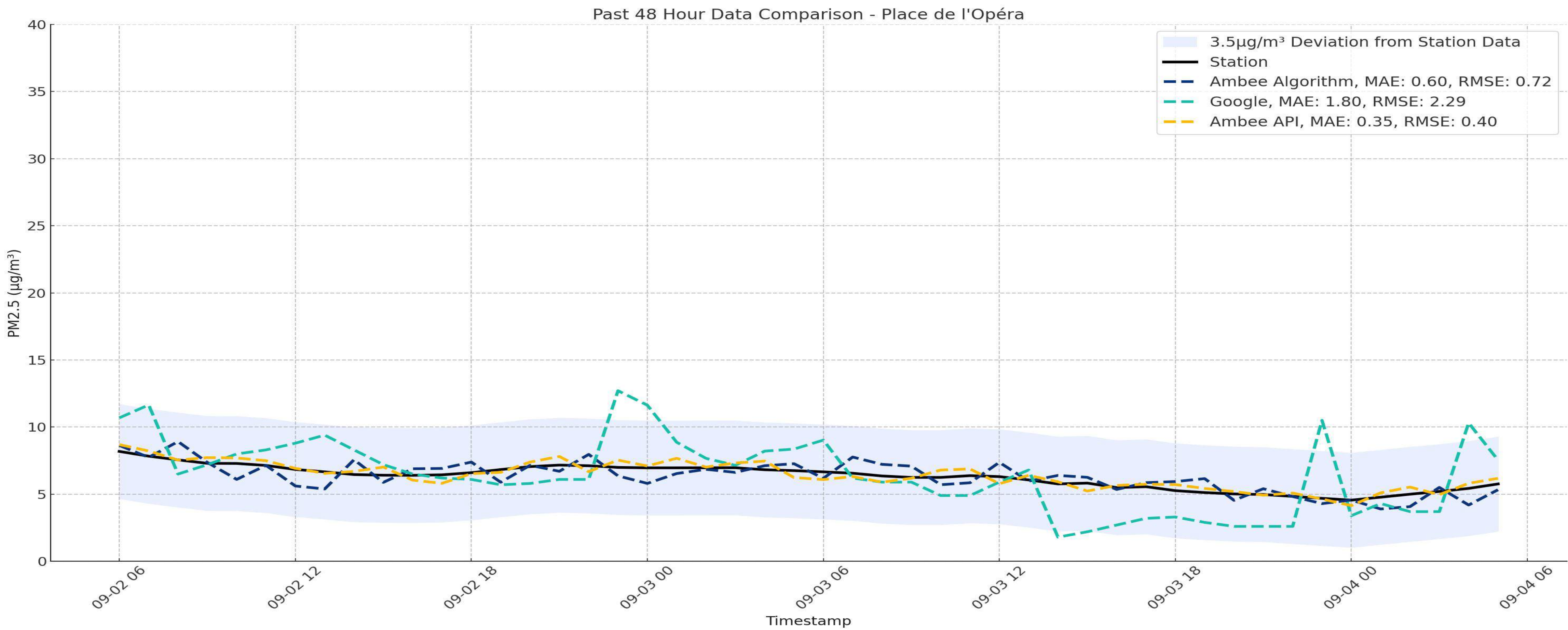


EXHIBIT 19 | Accuracy comparison between Ambee's live AQ and Google in Paris from 2nd to 4th September 2024

Comparing Ambee live AQ v. Google: EUR - Berlin, Germany LIVE

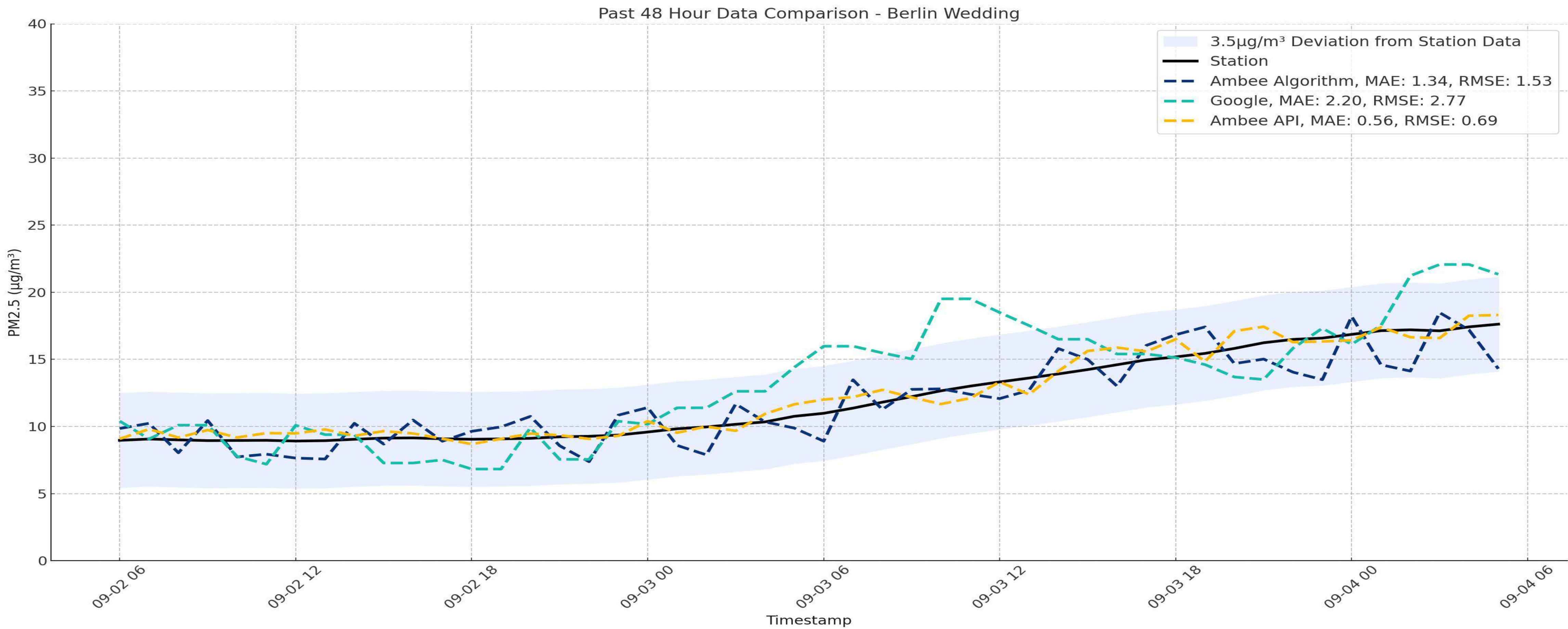


EXHIBIT 20 | Accuracy comparison between Ambee's live AQ and Google in Berlin from 2nd to 4th September 2024

Comparing Ambee live AQ v. Google: EUR - Brussels, Belgium LIVE

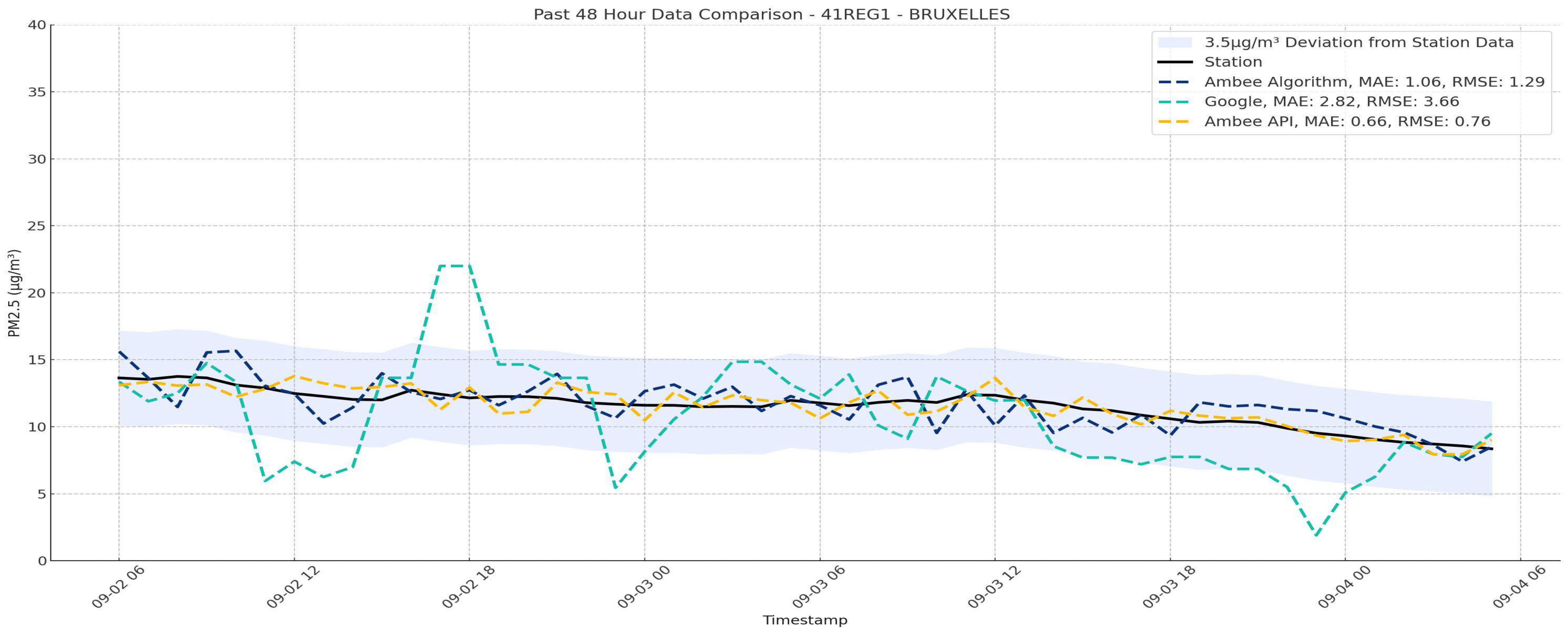


EXHIBIT 21 | Accuracy comparison between Ambee's live AQ and Google in Brussels from 2nd to 4th September 2024

Comparing Ambee's live AQ v. Google: EUR - Madrid, Spain LIVE

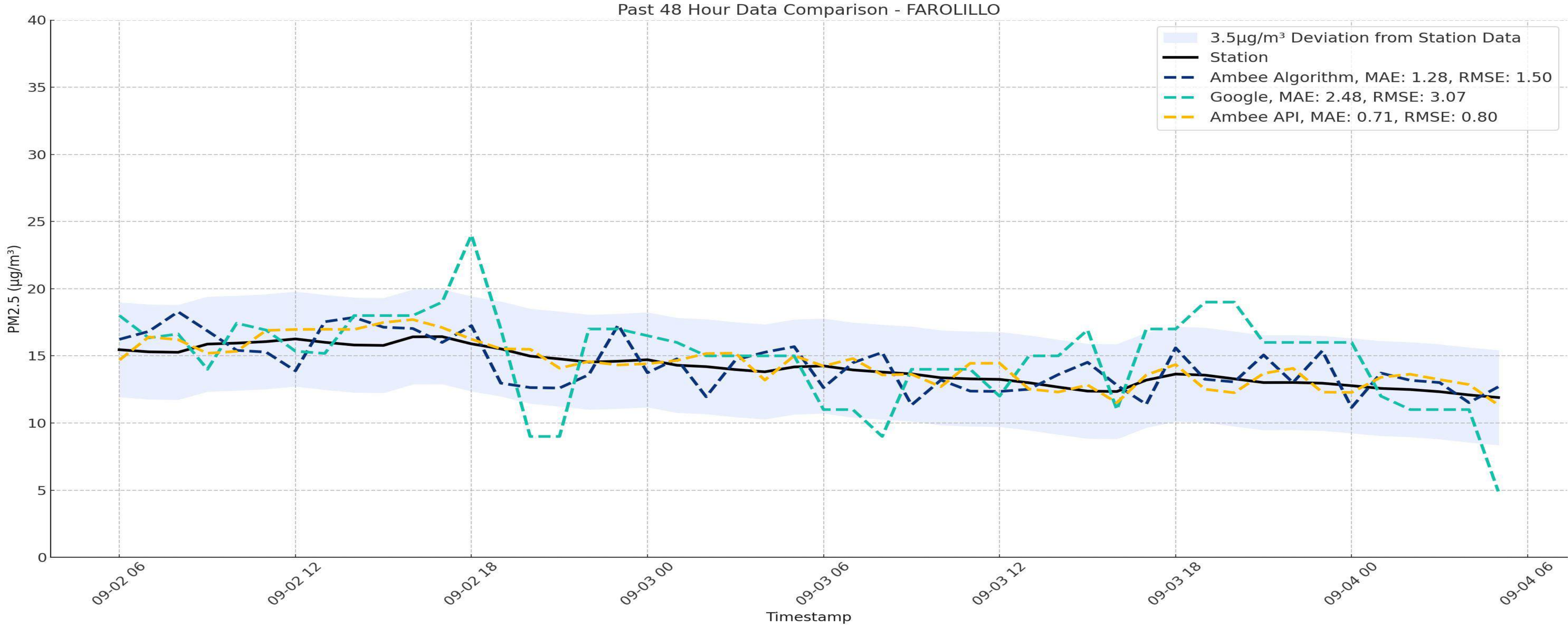


EXHIBIT 22 | Accuracy comparison between Ambee's live AQ and Google in Madrid from 2nd to 4th September 2024

Comparing Ambee's live AQ v. Google: AUS - Cammeray, New South Wales

LIVE

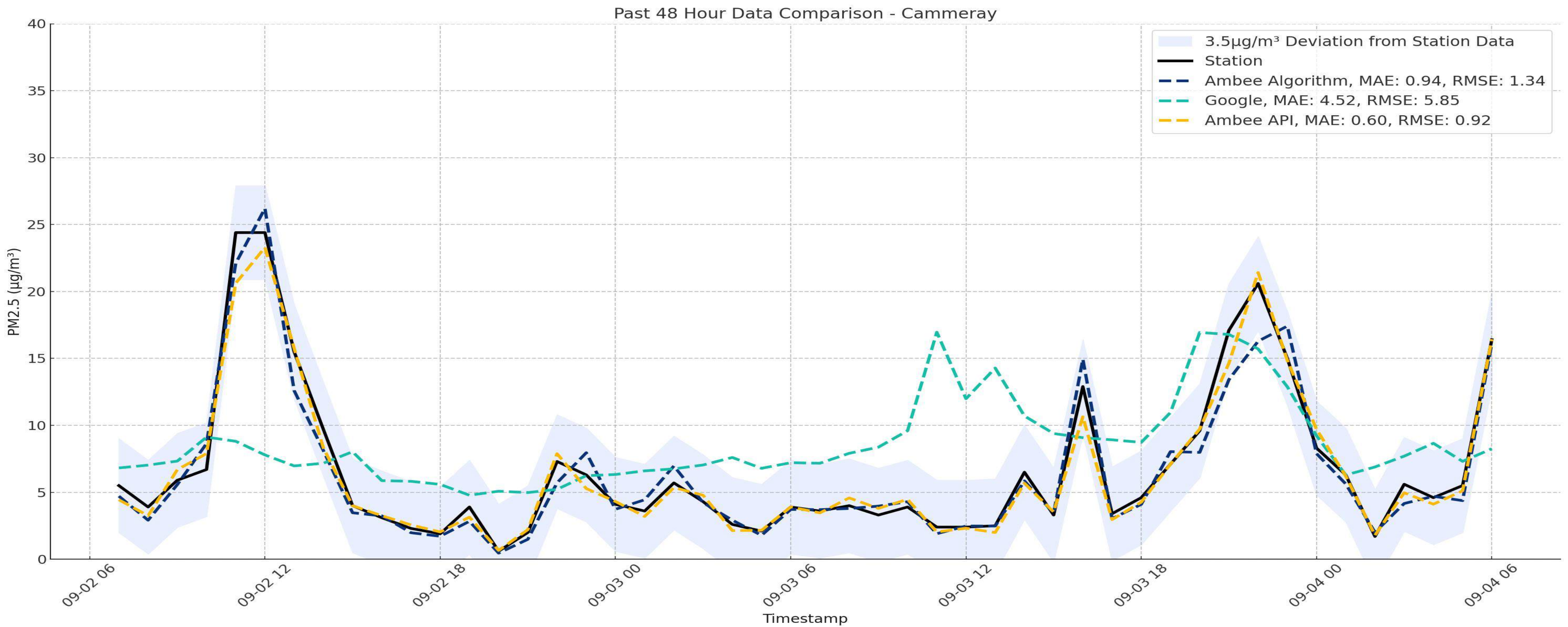


EXHIBIT 23 | Accuracy comparison between Ambee's live AQ and Google in Cammeray from 2nd to 4th September 2024

Comparing Ambee’s live AQ v. Google: AUS – Spotswood, Victoria LIVE

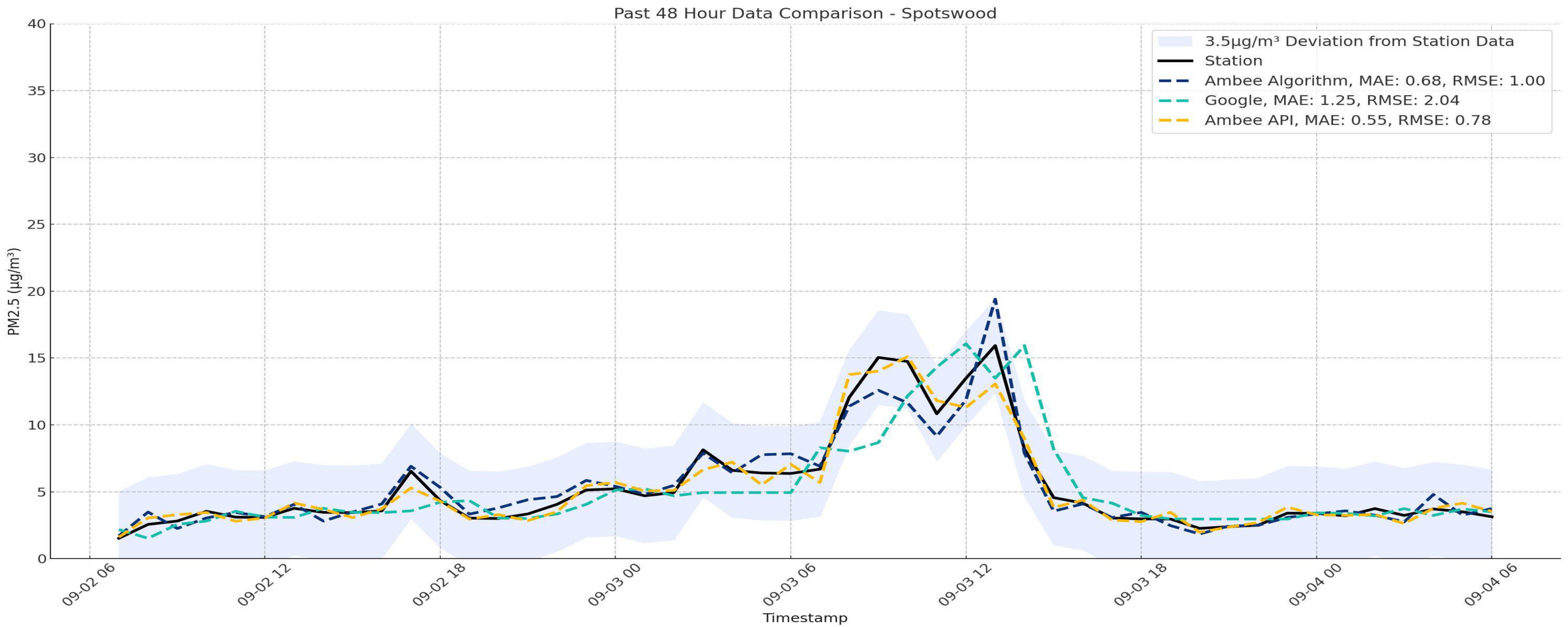


EXHIBIT 24 | Accuracy comparison between Ambee's live AQ and Google in Spotswood from 2nd to 4th September 2024

Comparing Ambee’s live AQ v. Google: AUS – Randwick, New South Wales

LIVE

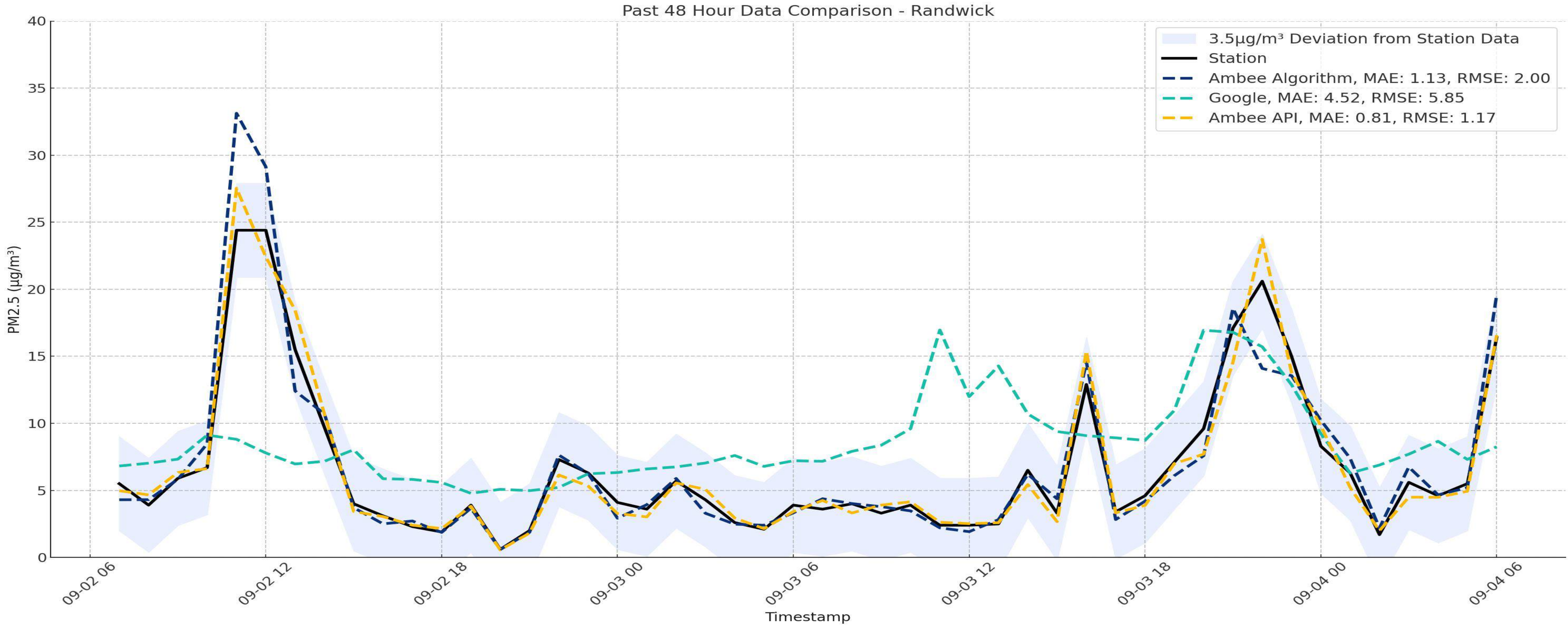


EXHIBIT 25 | Accuracy comparison between Ambee's live AQ and Google in Randwick from 2nd to 4th September 2024

Comparing Ambee's live AQ v. Google: ASIA - New Delhi, India (1) LIVE

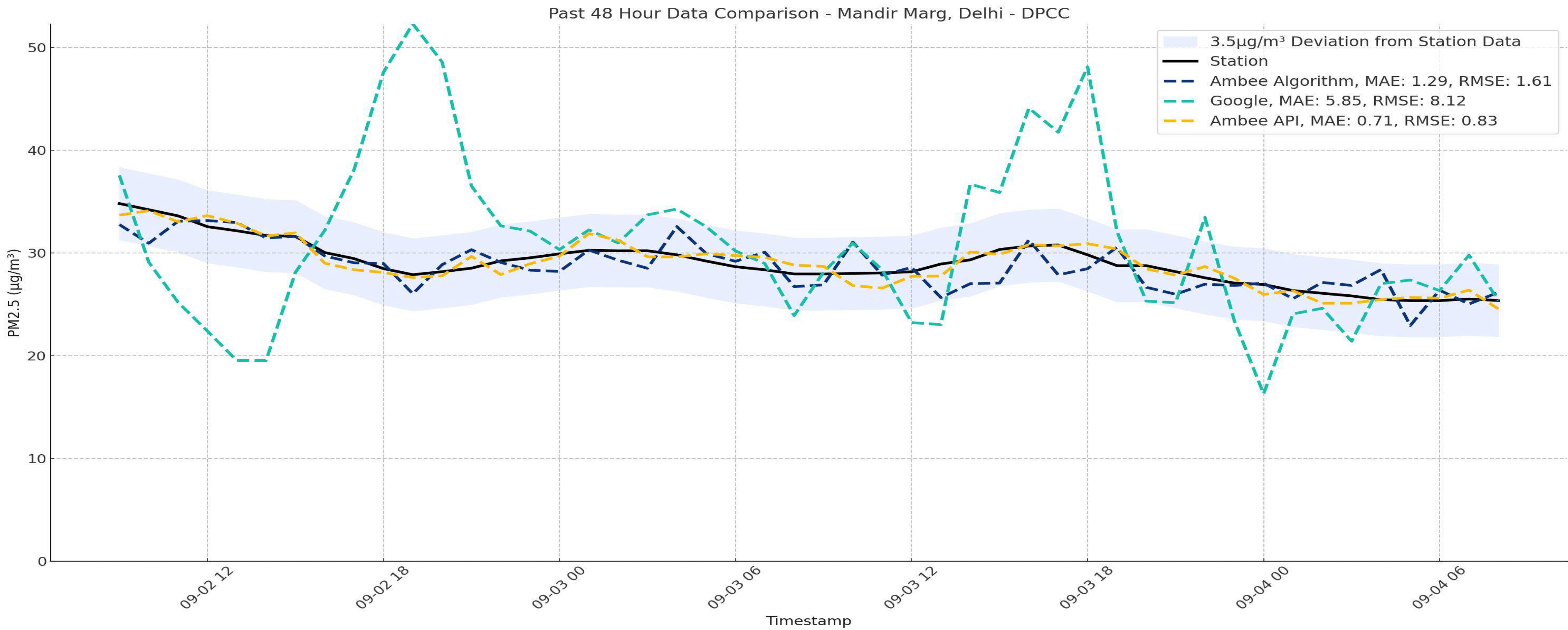


EXHIBIT 26.1 | Accuracy comparison between Ambee's live AQ and Google in New Delhi from 2nd to 4th September 2024

Comparing Ambee’s live AQ v. Google: ASIA – New Delhi, India (2) LIVE

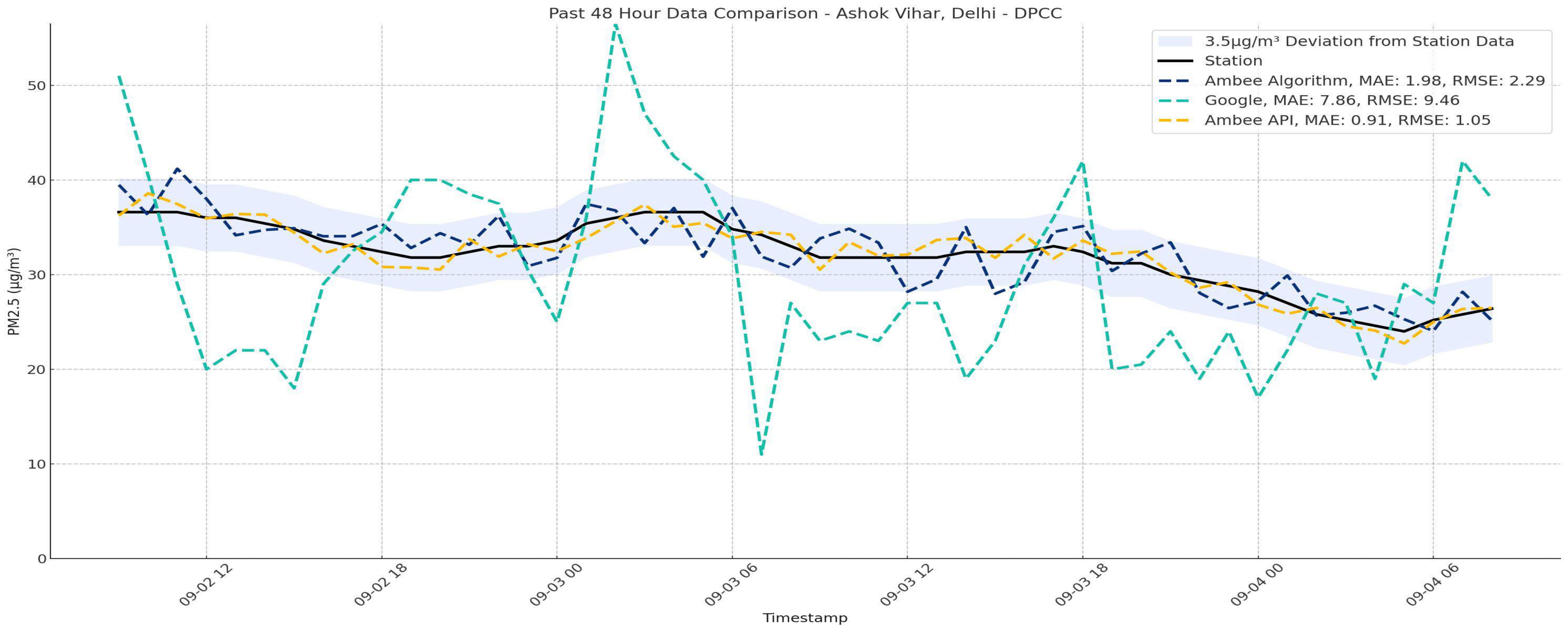


EXHIBIT 26.2 | Accuracy comparison between Ambee's live AQ and Google in New Delhi from 2nd to 4th September 2024

Comparing Ambee’s live AQ v. Google: ASIA – Bangalore, India (1) LIVE

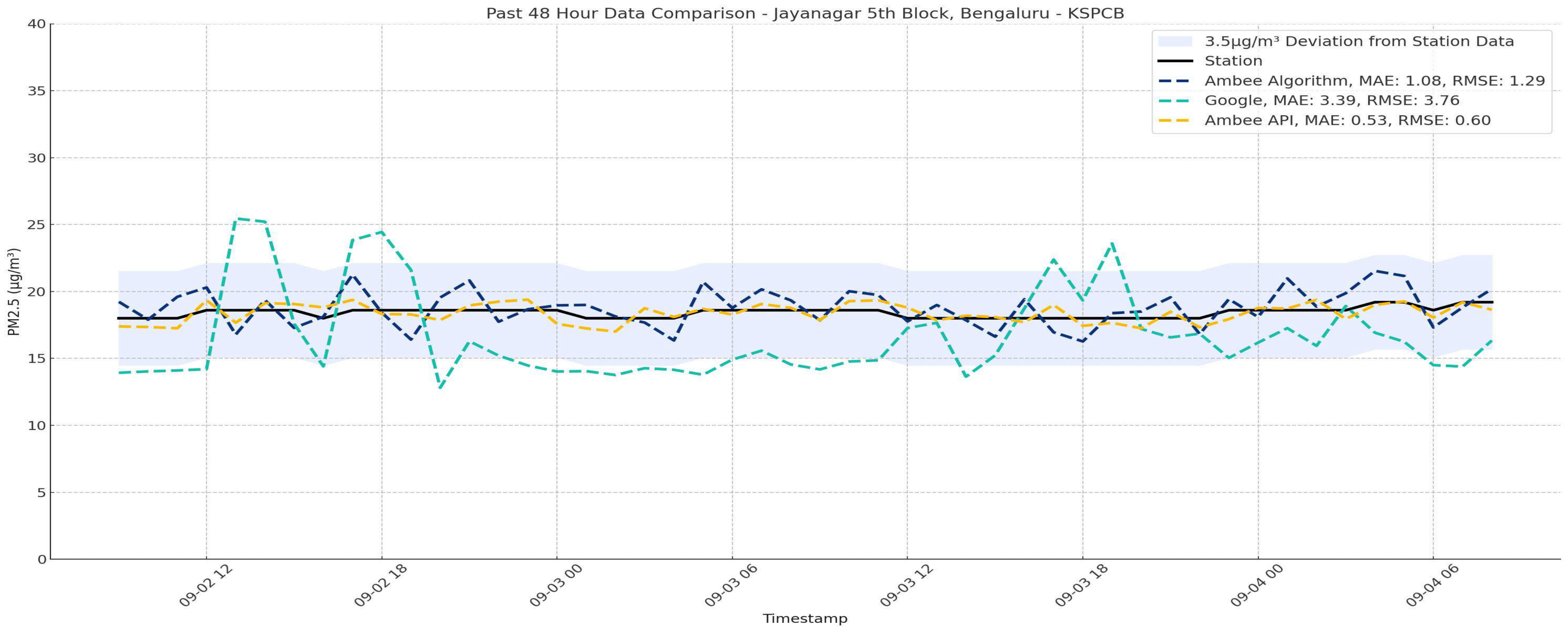


EXHIBIT 27.1 | Accuracy comparison between Ambee's live AQ and Google in Bangalore from 2nd to 4th September 2024

Comparing Ambee’s live AQ v. Google: ASIA – Bangalore, India (2) LIVE

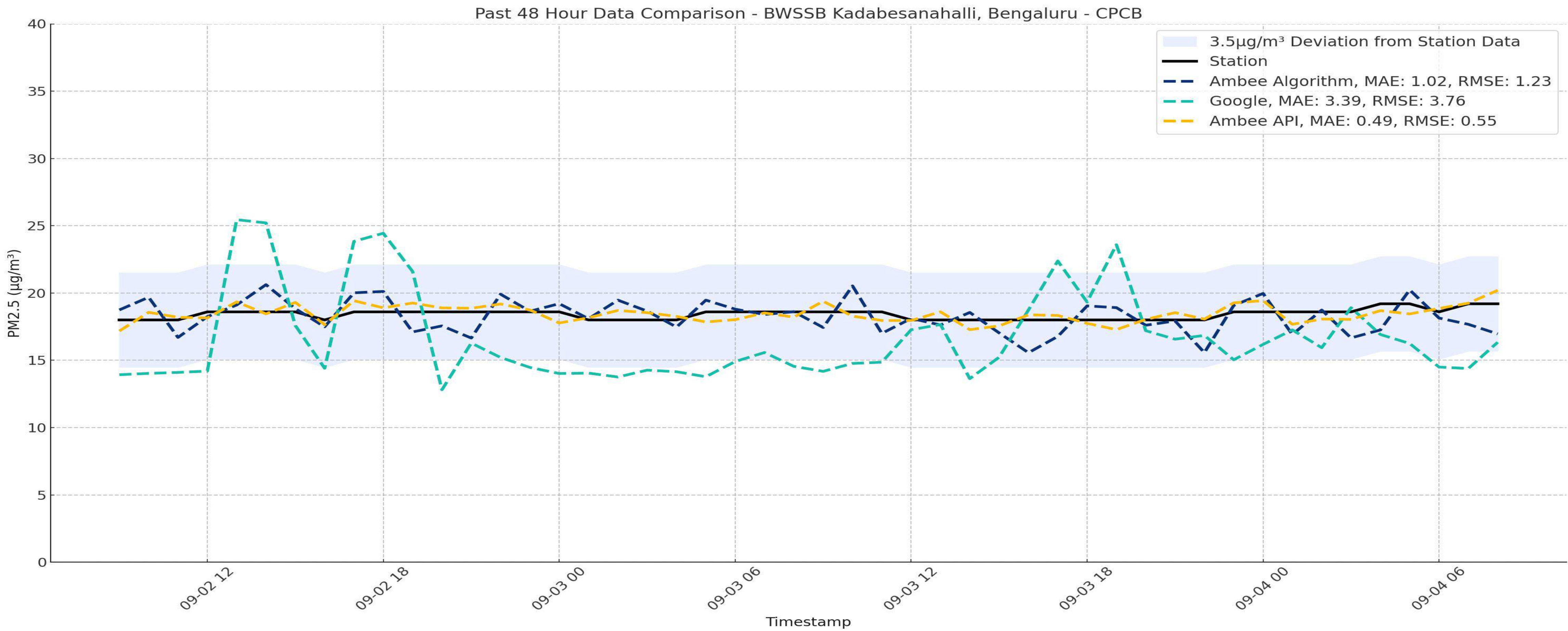


EXHIBIT 27.2 | Accuracy comparison between Ambee's live AQ and Google in Bangalore from 2nd to 4th September 2024

Comparing Ambee’s live AQ v. Google: ASIA – **Mumbai, India (1)** LIVE

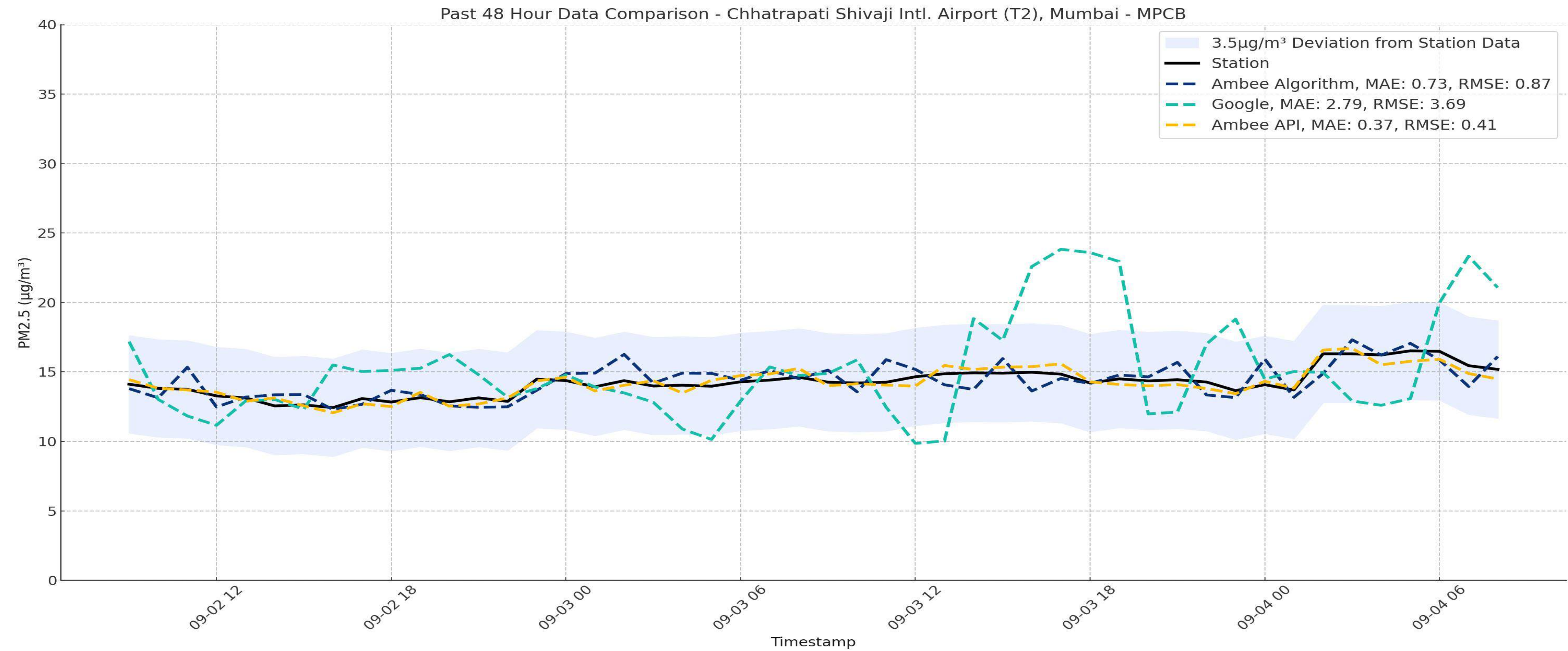


EXHIBIT 28.1 | Accuracy comparison between Ambee's live AQ and Google in Mumbai from 2nd to 4th September 2024

Comparing Ambee live AQ v. Google: ASIA - Mumbai, India (2) LIVE

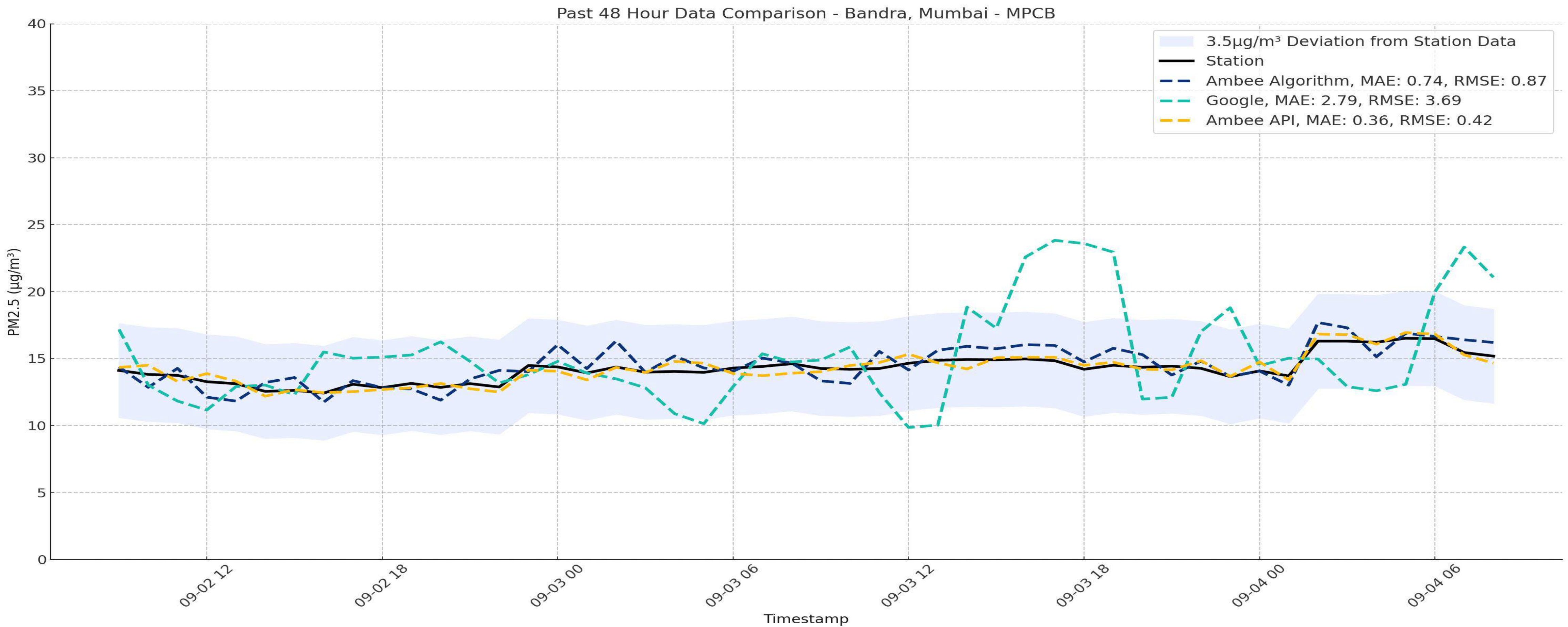


EXHIBIT 28.2 | Accuracy comparison between Ambee's live AQ and Google in Mumbai from 2nd to 4th September 2024

Comparing Ambee’s live AQ v. Google: ASIA – Tokyo, Japan LIVE

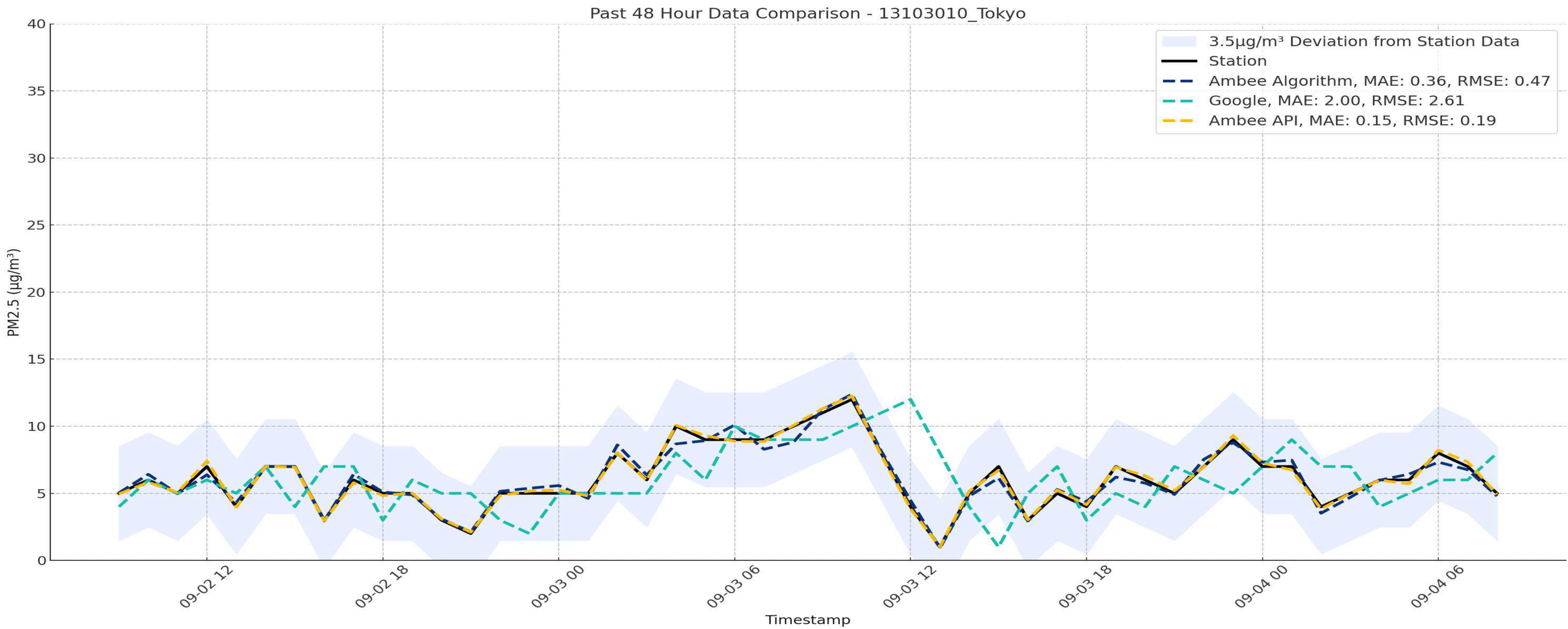


EXHIBIT 29 | Accuracy comparison between Ambee's live AQ and Google in Tokyo from 2nd to 4th September 2024

Benchmarking Ambee’s AQ forecast v. ground station: USA – Alamo Lake, Arizona

FORECAST

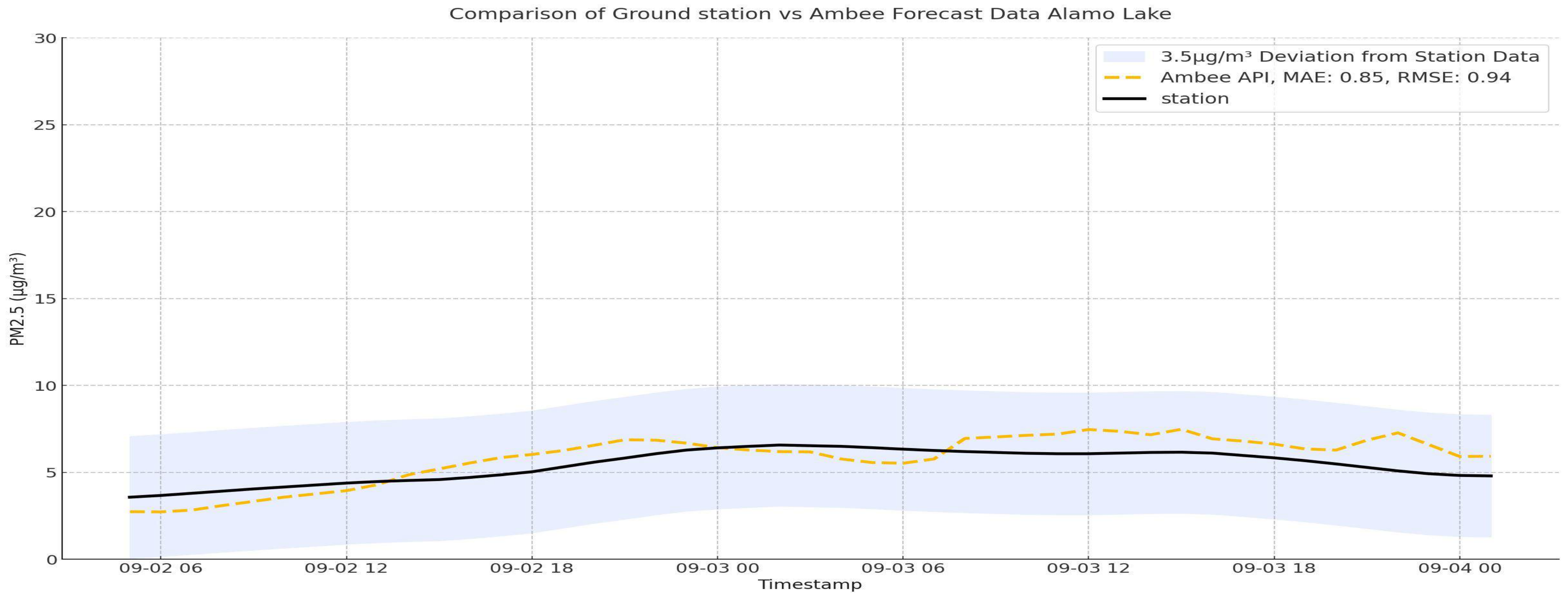


EXHIBIT 30 | Ambee forecast AQ v. ground station in Alamo Lake from 2nd to 4th September 2024

Benchmarking Ambee’s AQ forecast v. ground station: USA – Chehalis, Washington

FORECAST

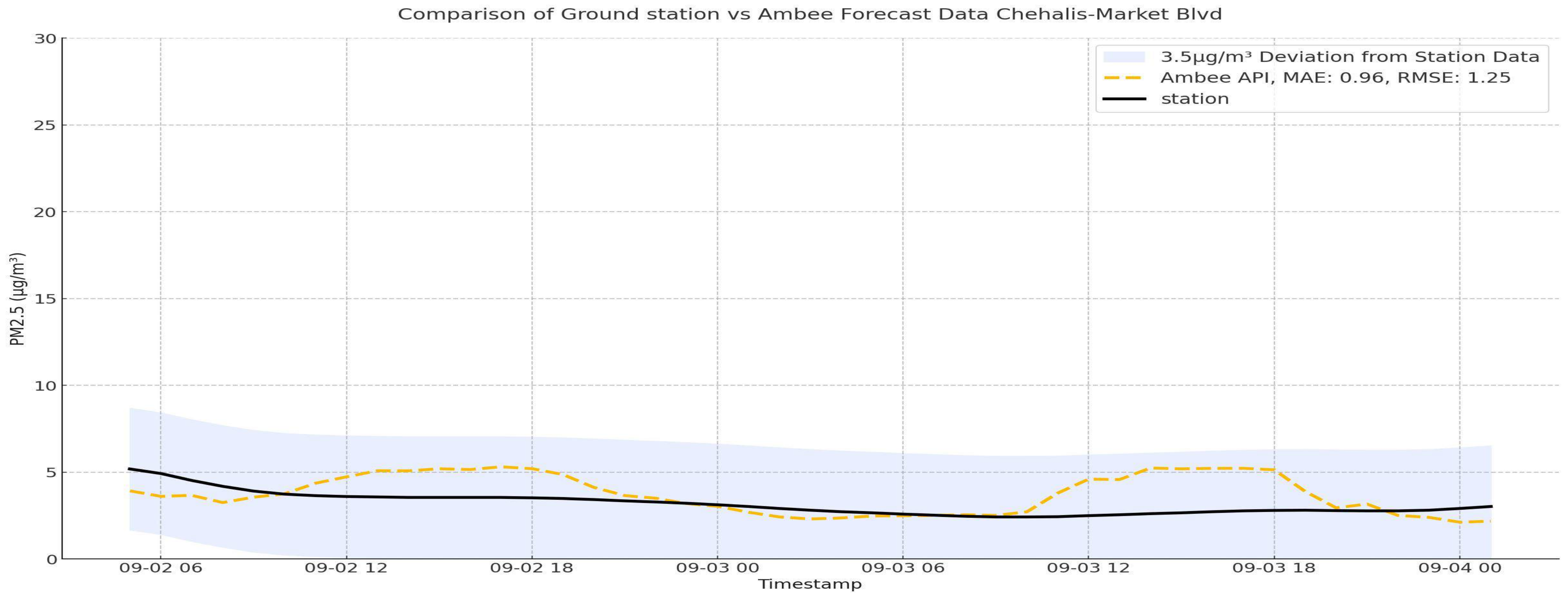


EXHIBIT 31 | Ambee forecast AQ v. ground station in Chehalis from 2nd to 4th September 2024

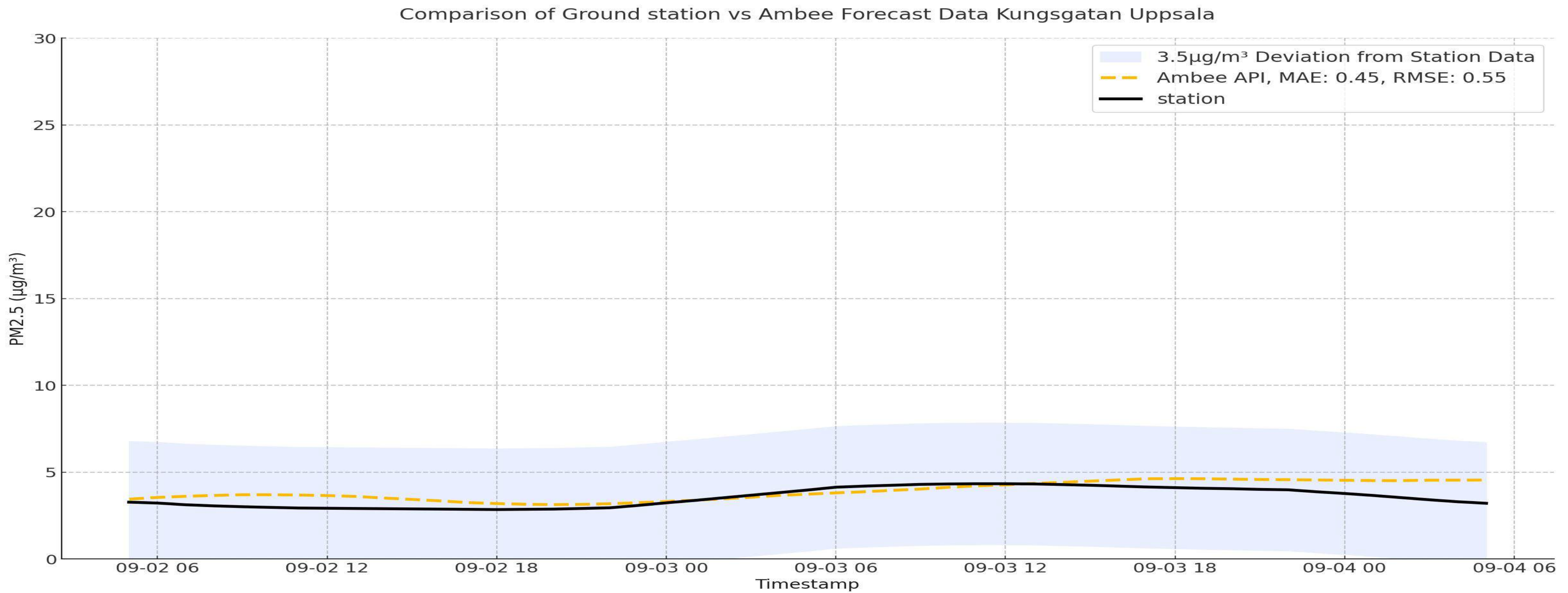


EXHIBIT 32 | Ambee forecast AQ v. ground station in Kungsgatan from 2nd to 4th September 2024

Benchmarking Ambee’s AQ forecast v. ground station: EUR – Eriksgatan, Sweden

FORECAST

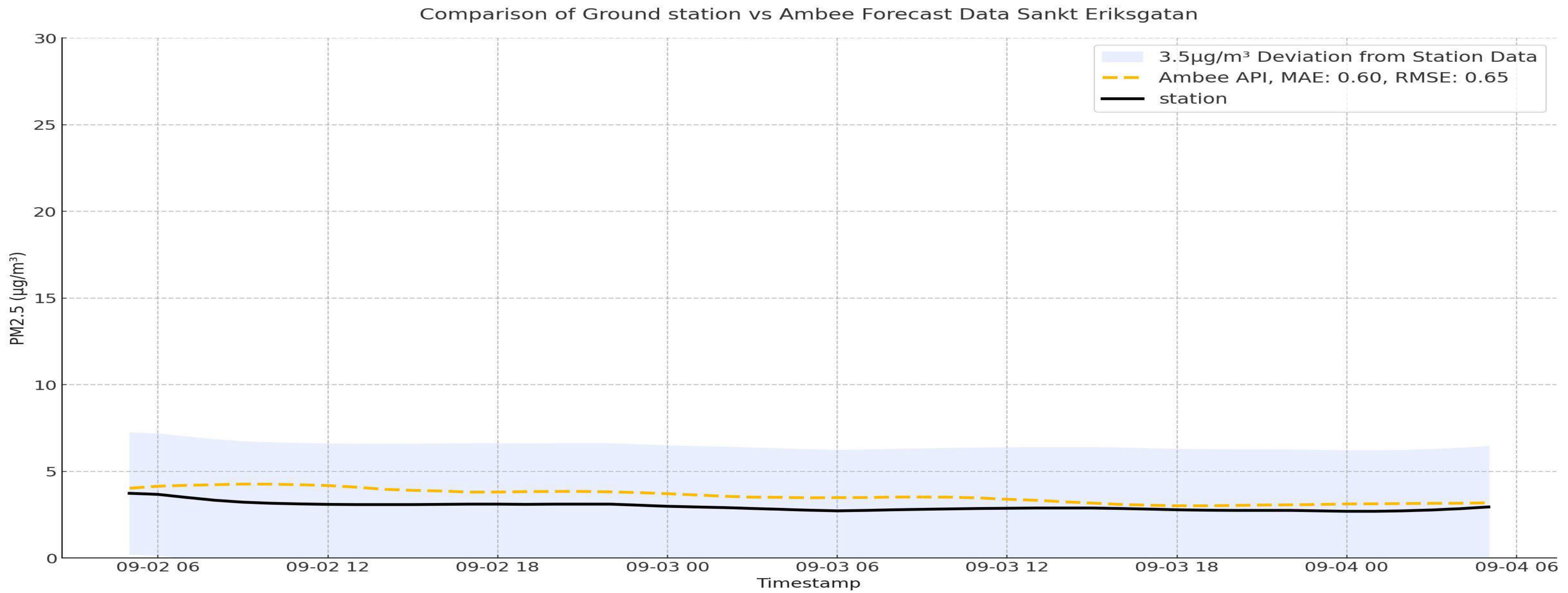


EXHIBIT 33 | Ambee forecast AQ v. ground station in Eriksgatan from 2nd to 4th September 2024

Benchmarking Ambee's AQ forecast v. ground-station: EUR - **Hornsgatan, Sweden** FORECAST

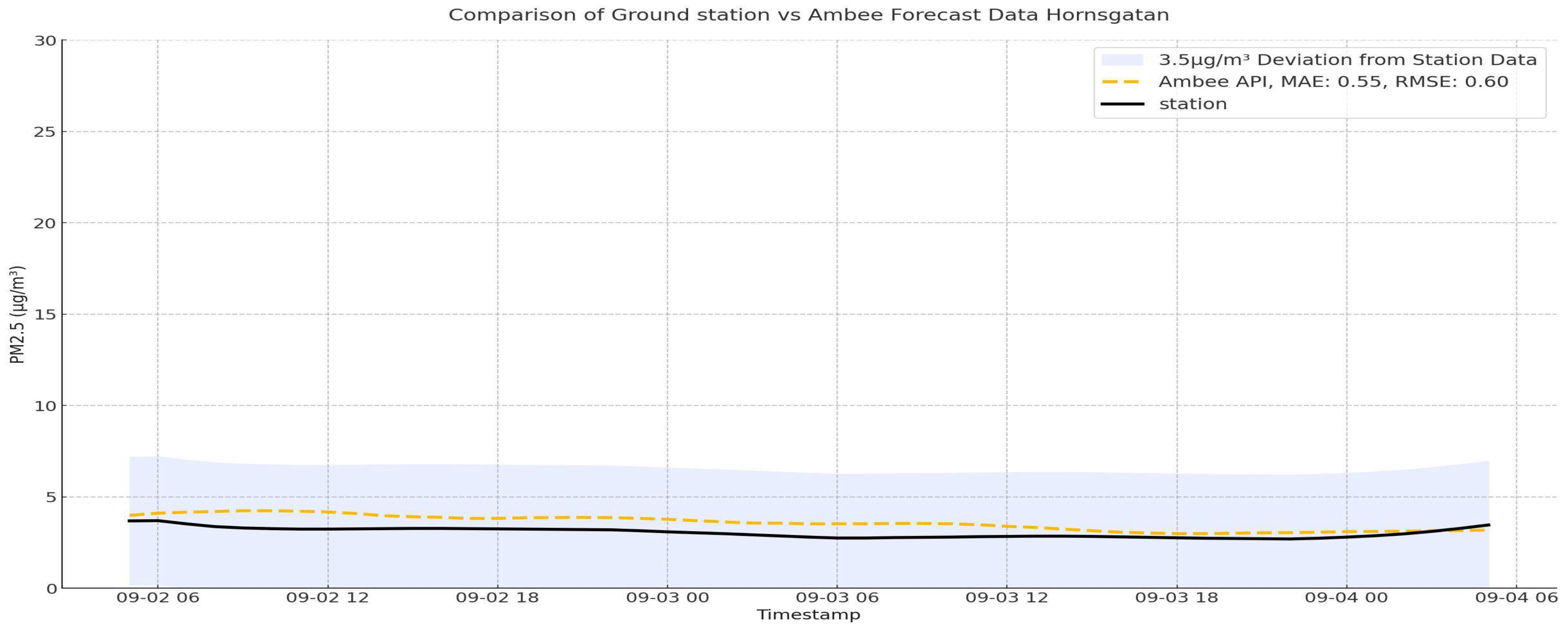


EXHIBIT 34 | Ambee forecast AQ v. ground station in Hornsgatan from 2nd to 4th September 2024

Benchmarking Ambee's AQ forecast v. ground station: EUR - Aylesford, England

FORECAST

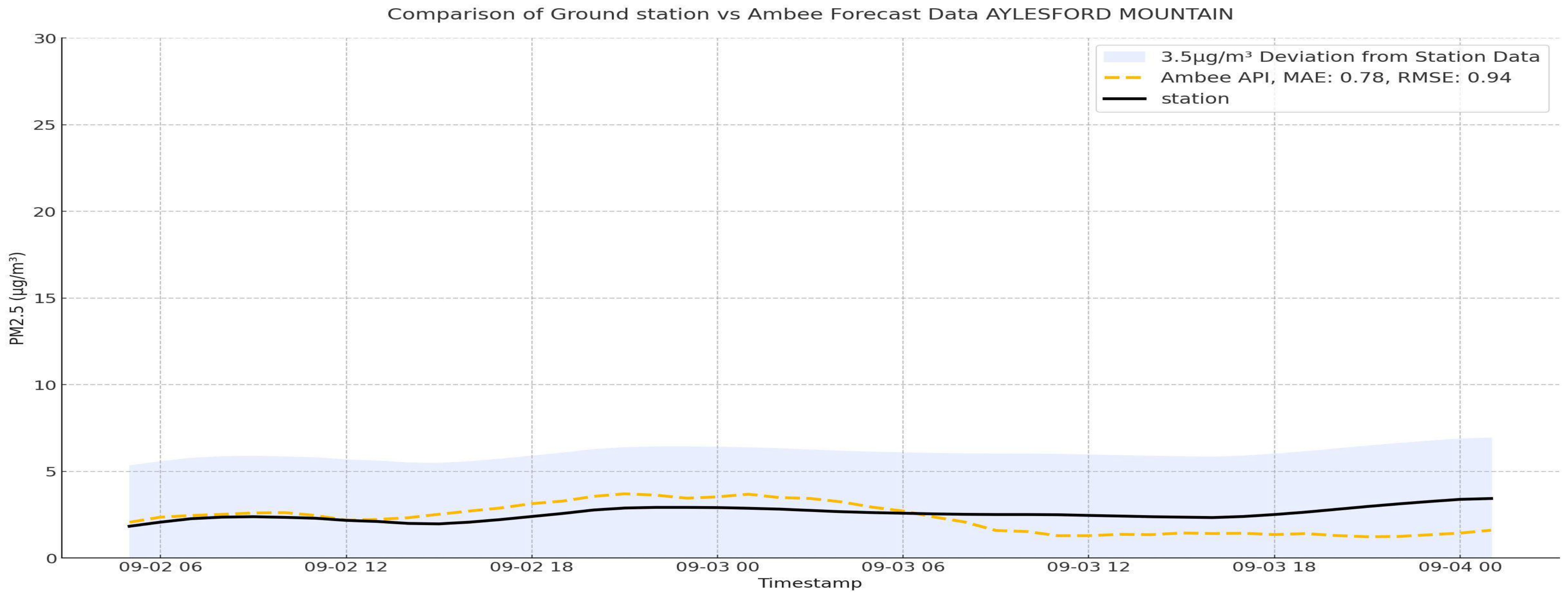


EXHIBIT 35 | Ambee forecast AQ v. ground station in Aylesford from 2nd to 4th September 2024

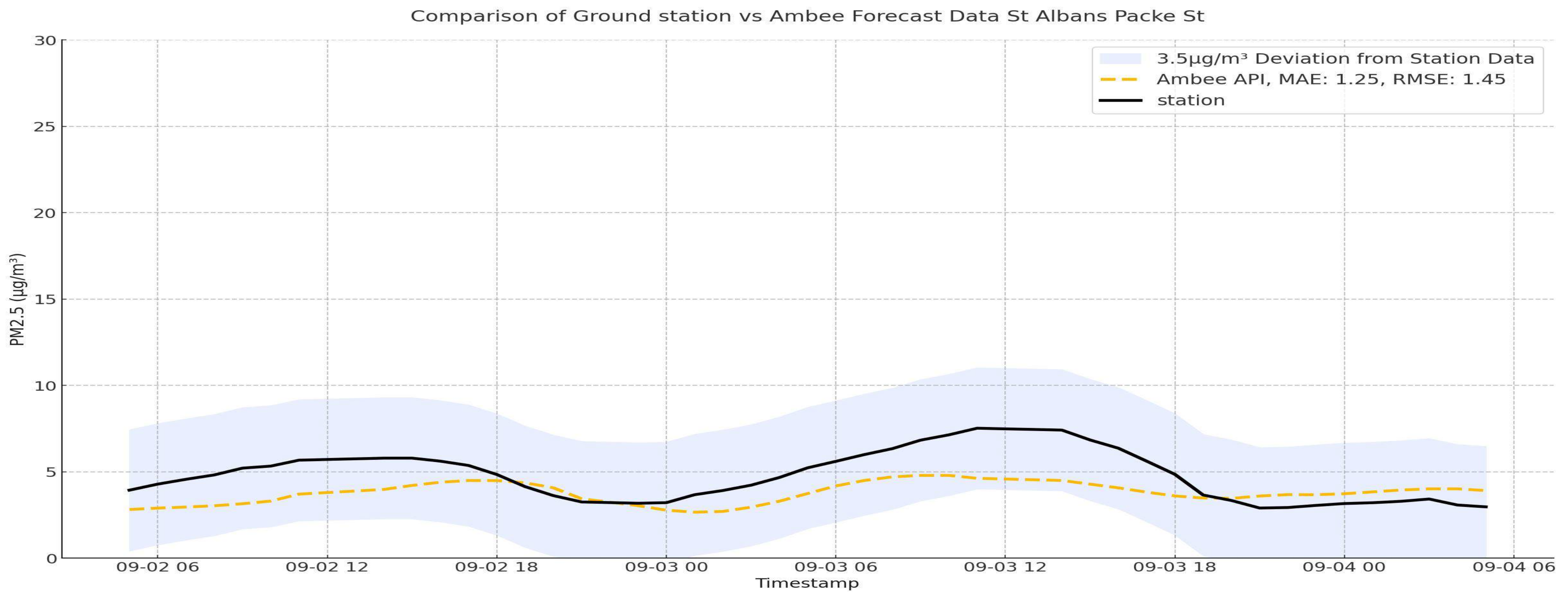


EXHIBIT 36 | Ambee forecast AQ v. ground station in St Albans from 2nd to 4th September 2024

Benchmarking Ambee’s AQ forecast v. ground station: EUR – Aberdeen, Scotland

FORECAST

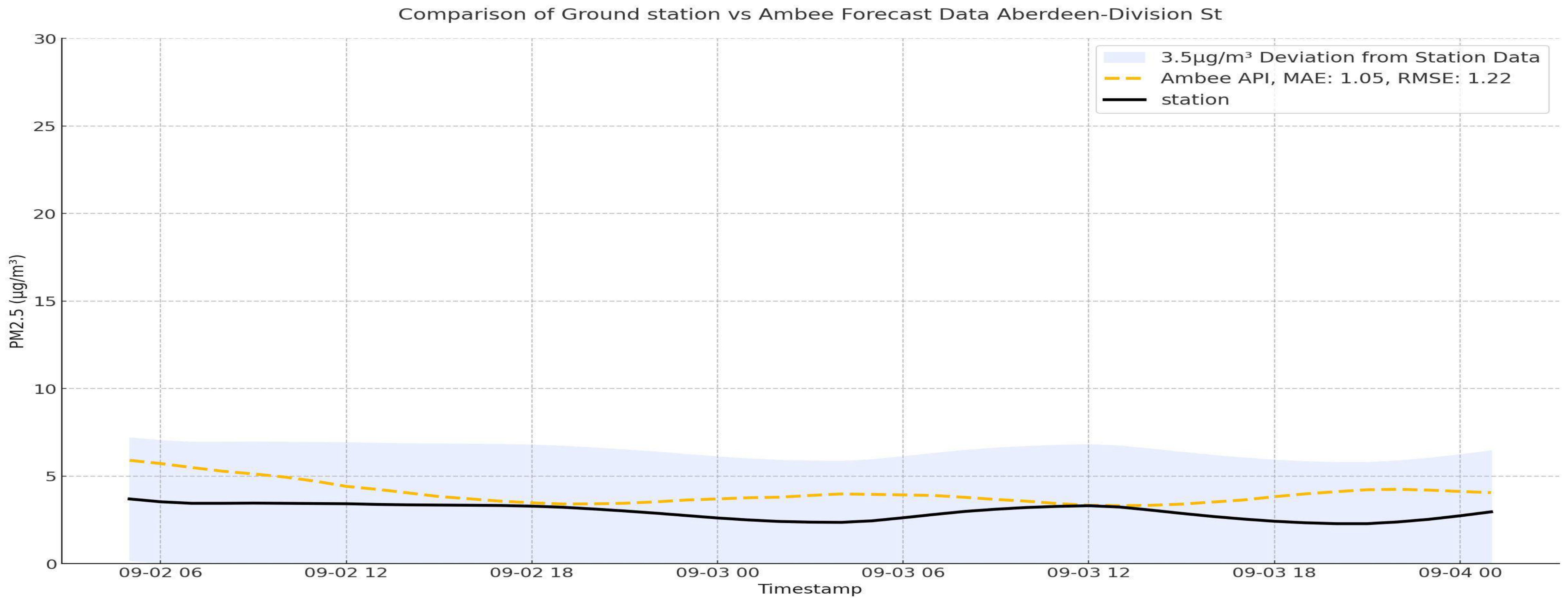


EXHIBIT 37 | Ambee forecast AQ v. ground station in Aberdeen from 2nd to 4th September 2024

Benchmarking Ambee's AQ forecast v. ground station: AUS - Cairns, Queensland

FORECAST

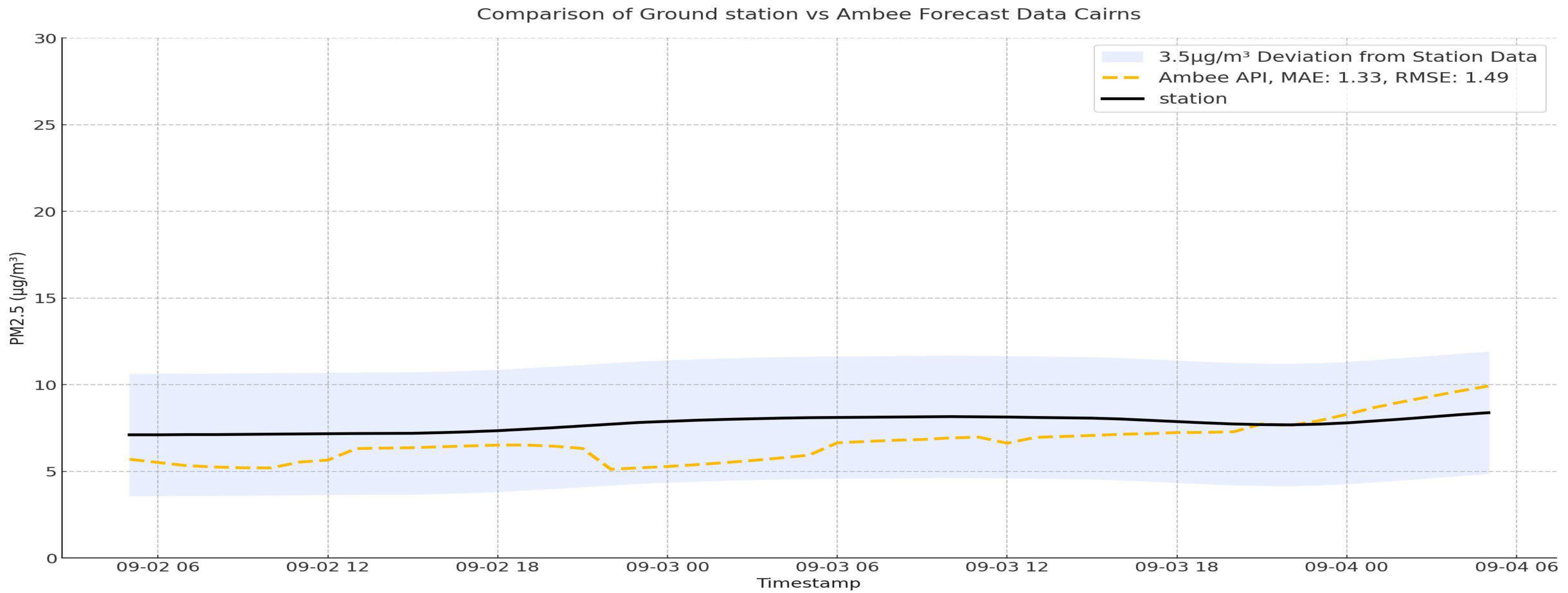


EXHIBIT 38 | Ambee forecast AQ v. ground station in Cairns from 2nd to 4th September 2024

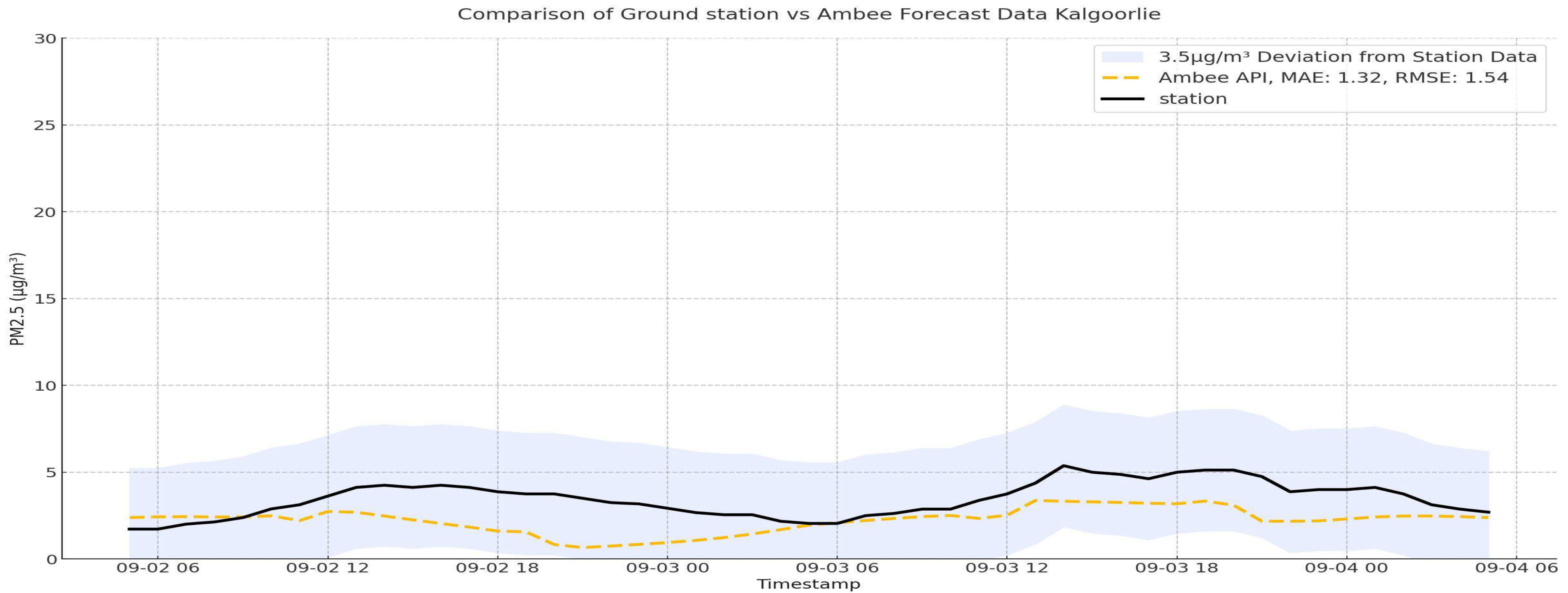


EXHIBIT 39 | Ambee forecast AQ v. ground station in Kalgoorlie from 2nd to 4th September 2024

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