

Ozone Tracker: Key Factors Affecting Ground-Level Ozone with AI Prediction

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Abstract

Ground-level ozone is an important air pollutant that often reaches high concentrations under strong sunlight and poses potential health risks. Because ozone is a secondary pollutant, its formation is strongly influenced by meteorological conditions.

In this study, hourly air quality and meteorological data from 2014 to 2024 in Taiwan were analyzed to investigate the relationships between ozone and key factors, including global solar radiation, precipitation, average wind speed, and NO_x concentration. Temporal variations and the effects of extreme weather events, such as typhoons, were also examined. Based on these results, an AI-based model was developed to predict ozone concentration for air quality assessment.

I. Research Motivation

In modern urban areas, air quality has become an important public issue.

Data from **air quality monitoring stations** show that **ozone (O₃)** often becomes the main pollutant on sunny afternoons.

Unlike primary pollutants, ozone is a **secondary pollutant** formed through **photochemical reactions**.

We are curious which **meteorological factors**—such as wind speed, precipitation, or nitrogen oxides (NO_x)—have the greatest impact on ozone levels.

With increasing **extreme weather**, events like typhoons also significantly affect **atmospheric stability** and pollutant dispersion.

Understanding these interactions and combining them with **AI technology** to build a **predictive system** can help the public anticipate ozone concentrations and protect respiratory health. This is the core motivation of our study.

II. Research Objectives

Tropospheric (ground-level) ozone is mainly formed when precursors, nitrogen oxides (NO_x) and volatile organic compounds (VOCs), undergo photochemical reactions under sunlight (UV).

And strong winds disperse and dilute ozone and its precursors, while precipitation removes water-soluble precursors to the ground.



The objectives of this study are:

1. Identify the most significant factors affecting ozone by performing **multivariable correlation analysis** on solar radiation, average wind speed, precipitation, and NO_x concentrations.

2. Examine the **patterns** of ozone variability across hourly, monthly, and yearly timescales to understand how these factors interact with ozone levels.

3. Investigate how unique environmental factors during **extreme weather** events, such as **typhoons**, affect ozone concentration changes.

4. Develop a **machine learning** model that **predicts** ozone levels based on specific meteorological parameters, transforming scientific observations into a practical digital tool for **smart city** environmental monitoring.

III. Research Methods

1. Multivariable Correlation Analysis

(1)Data Collection: Download hourly observational data over the past ten years from **government open data** platforms, including the **Taiwan EPA Air Quality Monitoring Network and Agricultural Meteorological Observation Network**.

(2)**Data Cleaning**: Remove extreme values or missing data caused by instrument errors to ensure analysis accuracy.

(3) Analysis of Ozone and Meteorological Factors

Use Excel to analyze the relationships between ozone and solar radiation, precipitation, average wind speed, and NO_x.

Plot dual-axis line charts to observe positive correlations and identify the factors with the greatest impact on ozone for further analysis.

2. Hourly / Monthly / Yearly Analysis

Use **Excel dual-axis line charts** to observe the relationships between the most influential factors and ozone across **different time scales**.

Summarize patterns across **daily hours**, **seasonal variations** (e.g., strong sunlight in summer vs weak sunlight in winter), and long-term **annual trends**.

Analyze the underlying causes driving these trends.

3. Case Study of **Extreme Weather** Events

Select **special cases** such as typhoon days and stationary fronts.

Analyze how **unusual conditions**—no sunlight, strong winds, precipitation, and sudden pressure changes— affect ozone concentrations and cause **deviations** from normal patterns.

4. Developing an **AI Model** to Predict Ozone Concentrations

(1) **Feature Selection**: Choose **three highly correlated factors** from the correlation analysis as input features.

(2) **Model Training**: Perform regression using **Random Forest** or a **simple Neural Network**.

(3) **Model Testing**: Evaluate the model on a test dataset not used in training, calculate the error between predicted and actual values, and adjust the model using a **loss function** for better accuracy.

IV. Preliminary Results

1. **Multivariable Correlation** Analysis

Plot hourly **dual-axis line charts** for the relationships between ozone concentrations and four factors:

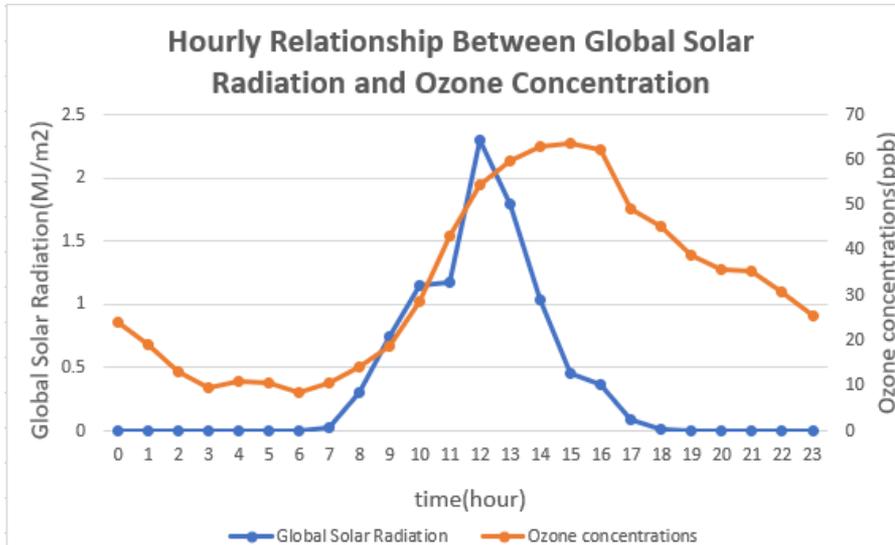
(1) Global Solar Radiation (2) Precipitation

(3) Average Wind Speed (4) NO_x

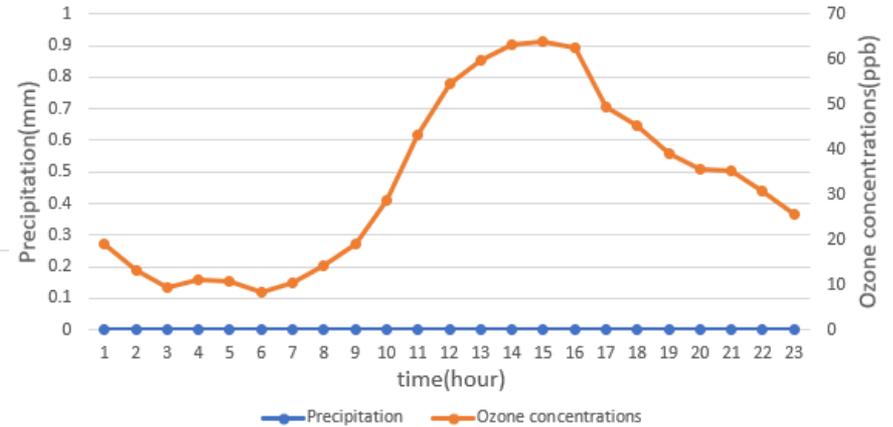
Concentration

Compare these factors to identify which has the **greatest impact on ozone levels.**

(Figure 1) Relationship between Global Solar Radiation and Ozone concentrations.

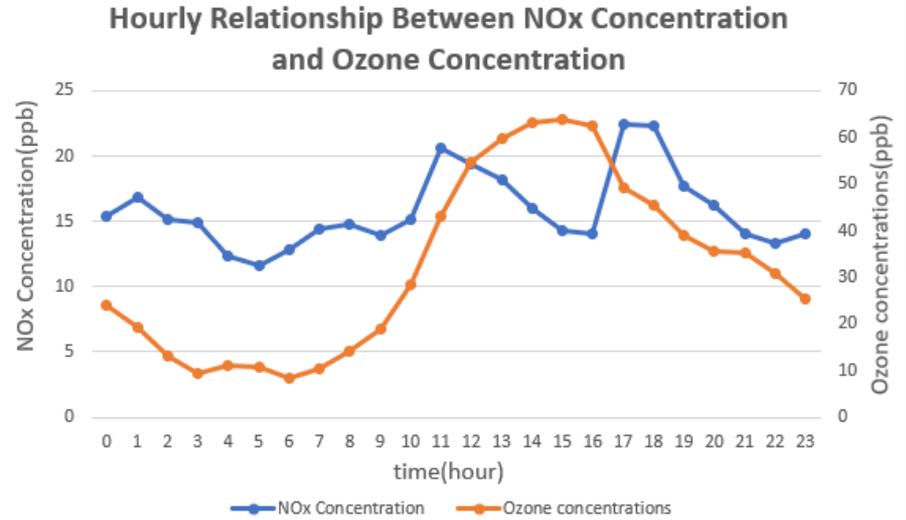
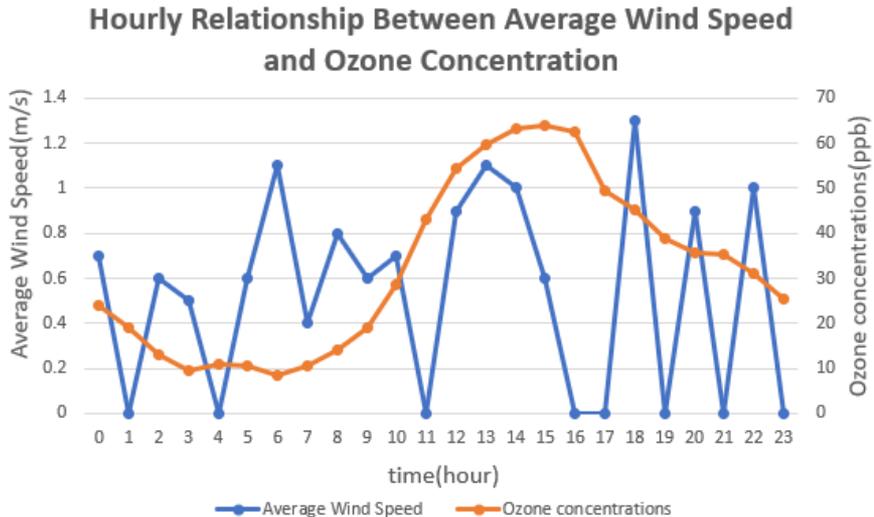


Hourly Relationship Between Precipitation and Ozone Concentration



(Figure 2) Relationship between Precipitation and Ozone concentrations.

(Figure 3) Relationship between Average Wind Speed and Ozone concentrations.



(Figure 4) Relationship between NOx Concentration and Ozone concentrations.

Observations from Figures 1–4

Global Solar Radiation increases from 0–12 h and decreases from 12–23 h, while Ozone increases from 0–15 h and decreases from 15–23 h.

The **positive correlation** between solar radiation and ozone is stronger than with the other three factors.

This indicates that **Global Solar Radiation** is the **most important factor** influencing **ozone** concentrations.

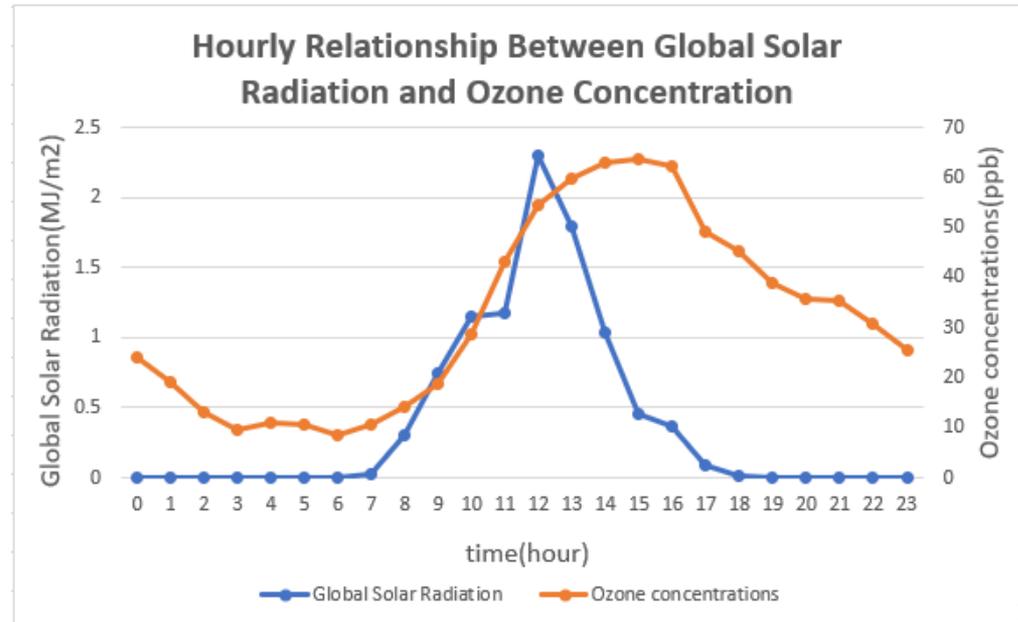
2. Hourly / Monthly / Yearly Analysis

(1) Hourly Analysis

Plot hourly ozone vs global solar radiation to examine short-term patterns.

(Figure 5)

Hourly relationship between Global Solar Radiation and Ozone concentrations.



Observations from Figure 5

Global Solar Radiation rises from 7:00 and peaks around 12:00.

Ozone is lowest at night and begins rising after sunrise.

Ozone typically peaks between 14:00–15:00, **lagging 2–3 hours behind** solar radiation.

It is speculated that although high solar radiation at noon provides abundant energy, the conversion of ozone precursors to ozone requires some **reaction time**.

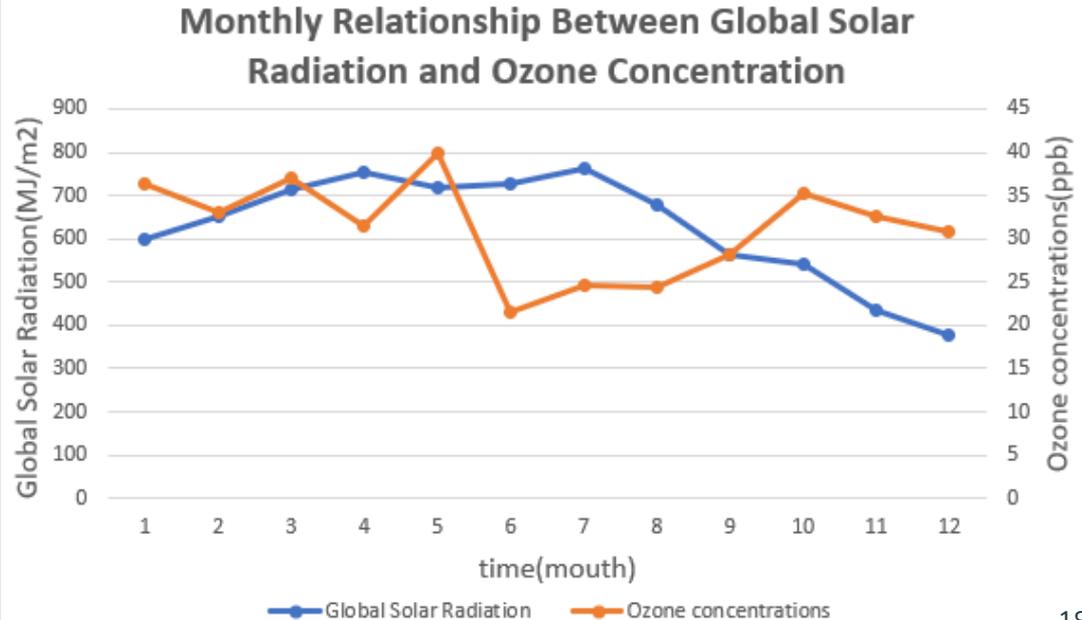
Additionally, stable **atmospheric convection** allows ozone to continue **accumulating**, causing ozone concentrations to peak slightly later, around 14:00–15:00.

This phenomenon is referred to as the “**ozone lag effect**.”

(2) Monthly Analysis

Plot monthly ozone vs global solar radiation to examine seasonal patterns.

(Figure 6) Monthly relationship between ozone and global solar radiation.



Observations from Figure 6

Global solar radiation ranges from 600–800 MJ/m² between February and September, and 300–600 MJ/m² between October and January.

Ozone concentrations are only 20–30 ppb **in summer** (April–June), much **lower** than 30–40 ppb in other seasons, **contrary to the expected** increase with higher summer solar radiation.

Speculation on Summer Ozone Trends

Strong solar radiation in summer enhances **vertical convection** and **raises the mixing layer height**, **diluting** ozone near the surface and **lowering its concentration**.

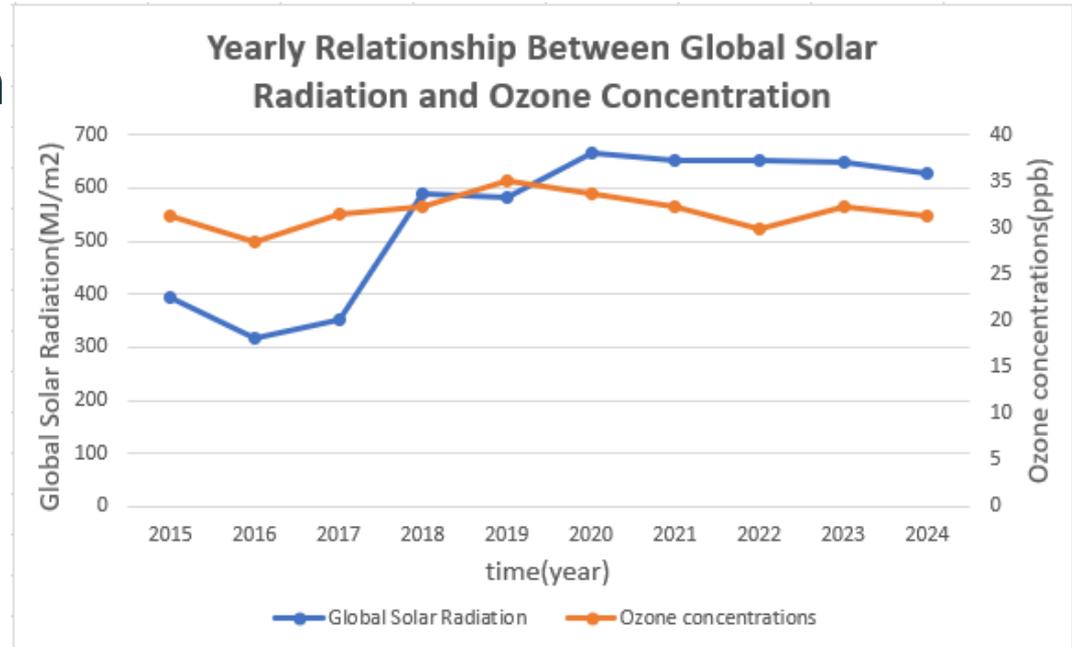
Frequent summer **precipitation** also removes ozone and its precursors through **washout effects**.

(3) Yearly Analysis

Plot yearly ozone vs global solar radiation to examine long-term patterns.

(Figure 7)

Yearly relationship between ozone and global solar radiation.



Observations from Figure 7

Between 2015 and 2024, **global solar radiation** shows a significant **increasing trend**, rising from approximately 400 MJ/m² initially to over 600 MJ/m² in recent years.

Ozone concentrations, however, remain **relatively stable**, fluctuating around 30–35 ppb over the same period.

Revised English Version (with Global Warming):

Ozone formation is not driven by solar radiation alone.

Ozone precursors have **stable long-term emissions**, and ozone **naturally decomposes**, keeping concentrations steady.

Global warming enhances vertical convection and raises the mixing layer height, while strong precipitation **prevents surface ozone from spiking** even under strong solar radiation.

V. Preliminary Conclusions

1. **Global solar radiation** is the primary factor affecting ozone concentrations.
2. Daily ozone peaks exhibit a **lag effect**.
3. Ozone concentrations are **lowest in summer**.
4. **Long-term** yearly ozone levels remain within a **stable range**.

VI. Future Work

1. Study of **Extreme Conditions** (e.g., Typhoon Days)

Analyze ozone under overcast skies with **no solar radiation** to **isolate** the effects of other factors.

Compare the impacts of **strong winds** and **heavy precipitation** on ozone concentrations.

Quantitatively investigate ozone accumulation caused by **descending airflows** during typhoons.

2. AI Model Optimization

Develop a **predictive AI** using **deep neural networks** and Random Forest, adjusting variable weights via a loss function to improve accuracy.

Train the model with **easily accessible factors** related to ozone, such as temperature, season, and rainfall.

Create a **visualization tool** that allows users to input data and receive real-time, accurate ozone predictions to support **public health protection**.

3. Cross-Regional Comparison

Incorporate data from **different areas** (e.g., industrial vs residential zones) to test the **generalization ability** of the AI model.

Add new relevant variables as needed to ensure the model can be **applied regardless of environment**.

VII. References and Data Sources

1. Agricultural Meteorological Observation Network (AMON) Monitoring System(<https://agr.cwa.gov.tw/monitor>)
2. Air Quality Monitoring Network, Ministry of Environment (<https://airtw.moenv.gov.tw/>)
3. Animal and Plant Health Inspection Agency (APHIA), Ministry of Agriculture (MOA) /Ozone pollution (https://www.aphia.gov.tw/publish/sweet/sweet_Pdf/04-12.pdf)
4. Hon Hai Precision Industry Co., Ltd. https://www.richintech.com/technology_detail/machine-learning/