Jianzheng Liu, Jie Li, Weifeng Li. 2016. Temporal Patterns in Fine Particulate Matter Time Series in Beijing: A Calendar View. *Scientific Report*. doi: 10.1038/srep32221.

Temporal Pattern of Fine Particulate Matter Time Series in Beijing

A Calendar View

Jianzheng Liu 刘建政

Email: jzliu.100@gmail.com
Web: http://www.jzliu.net/

THE UNIVERSITY OF HONG KONG 香港大學
faculty of architecture 建築學院
Centre of Urban Studies and Urban Planning 城市研究及城市規劃中心
Department of Urban Planning and Design 城市規劃及設計系

Does $PM_{2.5}$ concentration follows the a priori seasonal, or weekly patterns in Beijing?

Image courtesy of www.china.org.cn

北京$PM_{2.5}$真如一些研究中所表述那樣有季節月份和周的變化規律嗎？

1

1 Significance
研究的意義

Overly high fine particulate matter ($PM_{2.5}$) concentration in Beijing has become a new symbol of Beijing in addition to its figure as capital city in China.

"Capital of Smog" used to denote London 60 years ago now falls upon Beijing, posing a critical challenges to its sustainable development that leads to major public health concerns.

Image courtesy: www.theweek.co.uk

Image courtesy: www.japantimes.co.jp

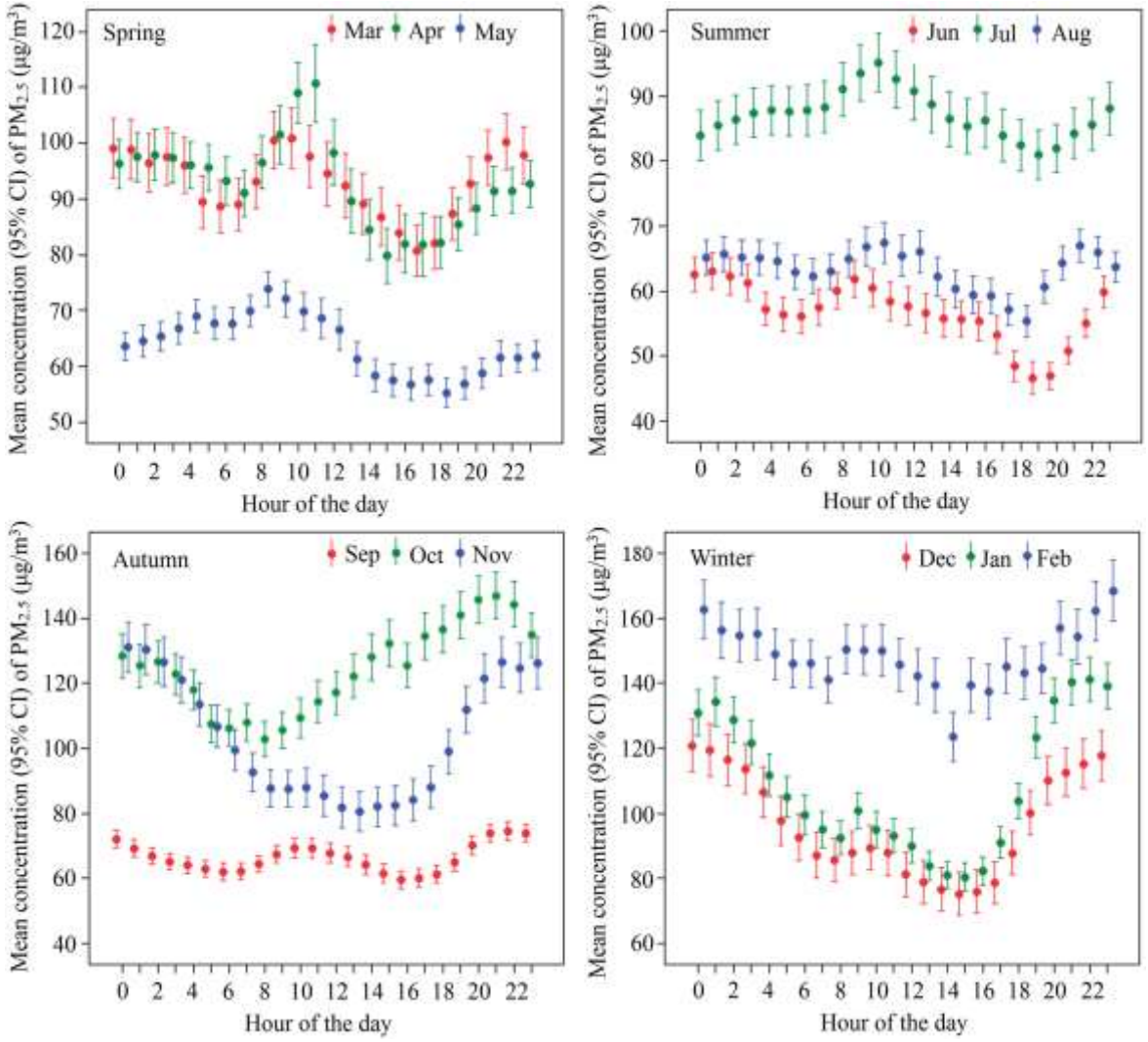
We need knowledge of $PM_{2.5}$.

Image courtesy of www.cbc.ca

Research Gaps

- Current studies on temporal patterns of $PM_{2.5}$ used a priori assumption that $PM_{2.5}$ concentration follows seasonal, monthly or weekly patterns (Chen et al., 2015; Huang et al., 2015; Y. Wang, Ying, Hu, & Zhang, 2014; Zhang & Cao, 2015).

These studies tried to **fit** the $PM_{2.5}$ concentration to imposed seasonal or monthly or weekly patterns



(Huang et al., 2015)

the arbitrary seasonal division of variation in $PM_{2.5}$ concentration may result in information loss and conceal potentially important insights.

The variation of $PM_{2.5}$ concentration may vary on different time scales other than these predefined scales.

Purpose

- Instead of making arbitrary assumptions on weekly, monthly, and seasonal patterns,
  we prefers to let the data show itself on a daily basis through visualization (show the data in a calendar).

- To achieve that, we conduct two time-series cluster analysis to reveal the pattern of $PM_{2.5}$ temporal variation in much more detail.

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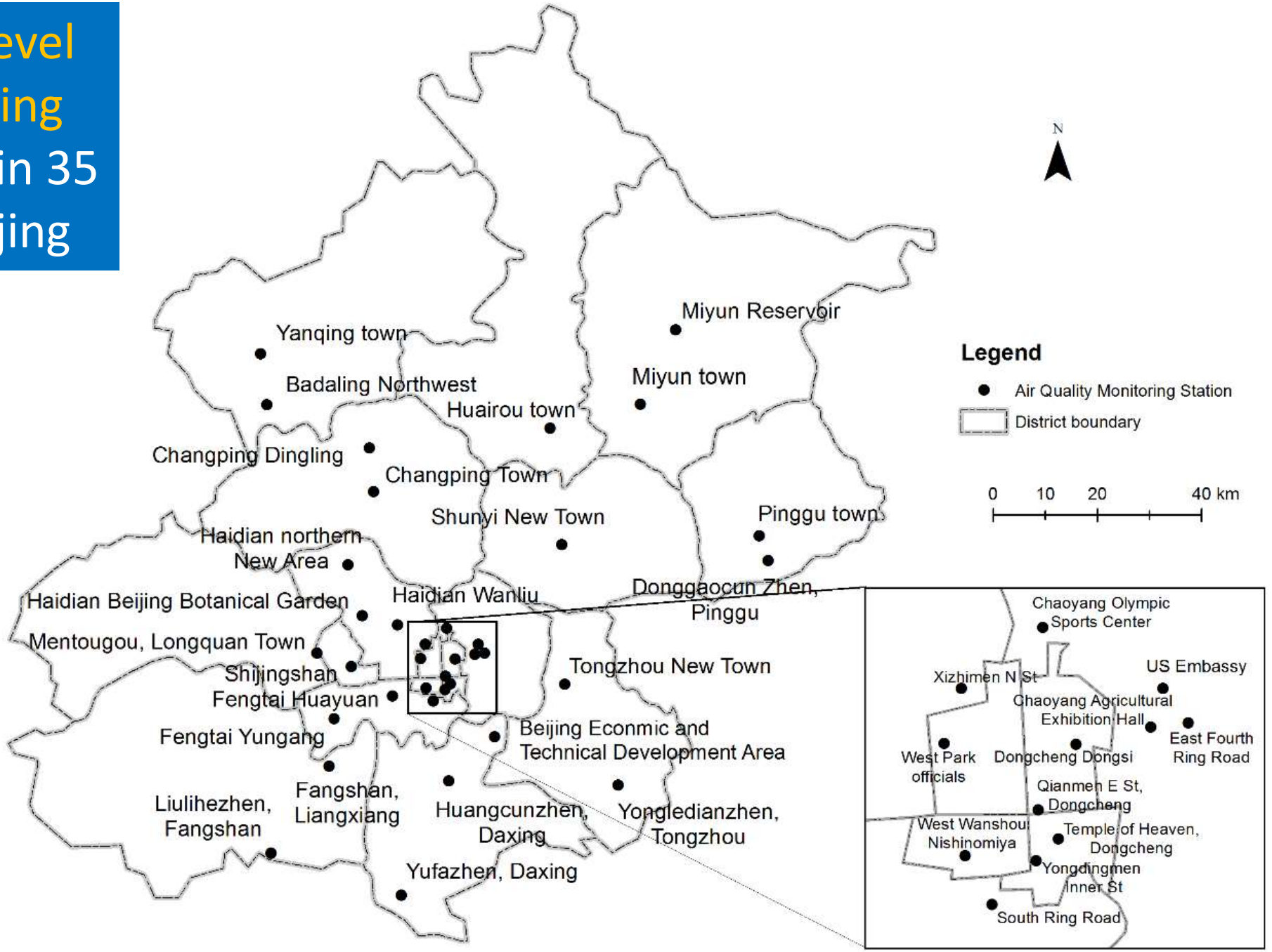
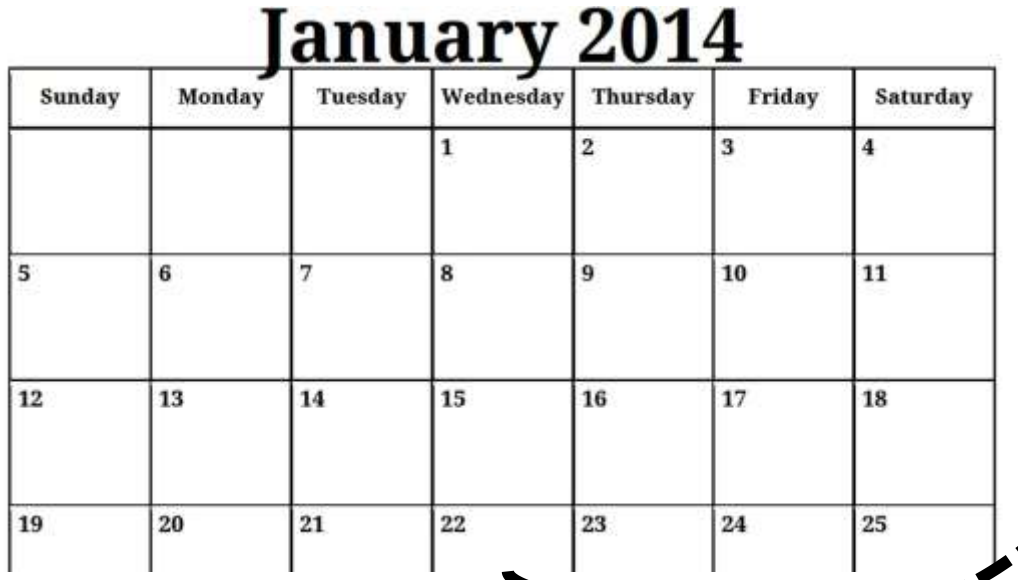
2 Data & Methodology
數據和研究方法

One-year ground level air quality monitoring data in 2014 from in 35 stations across Beijing

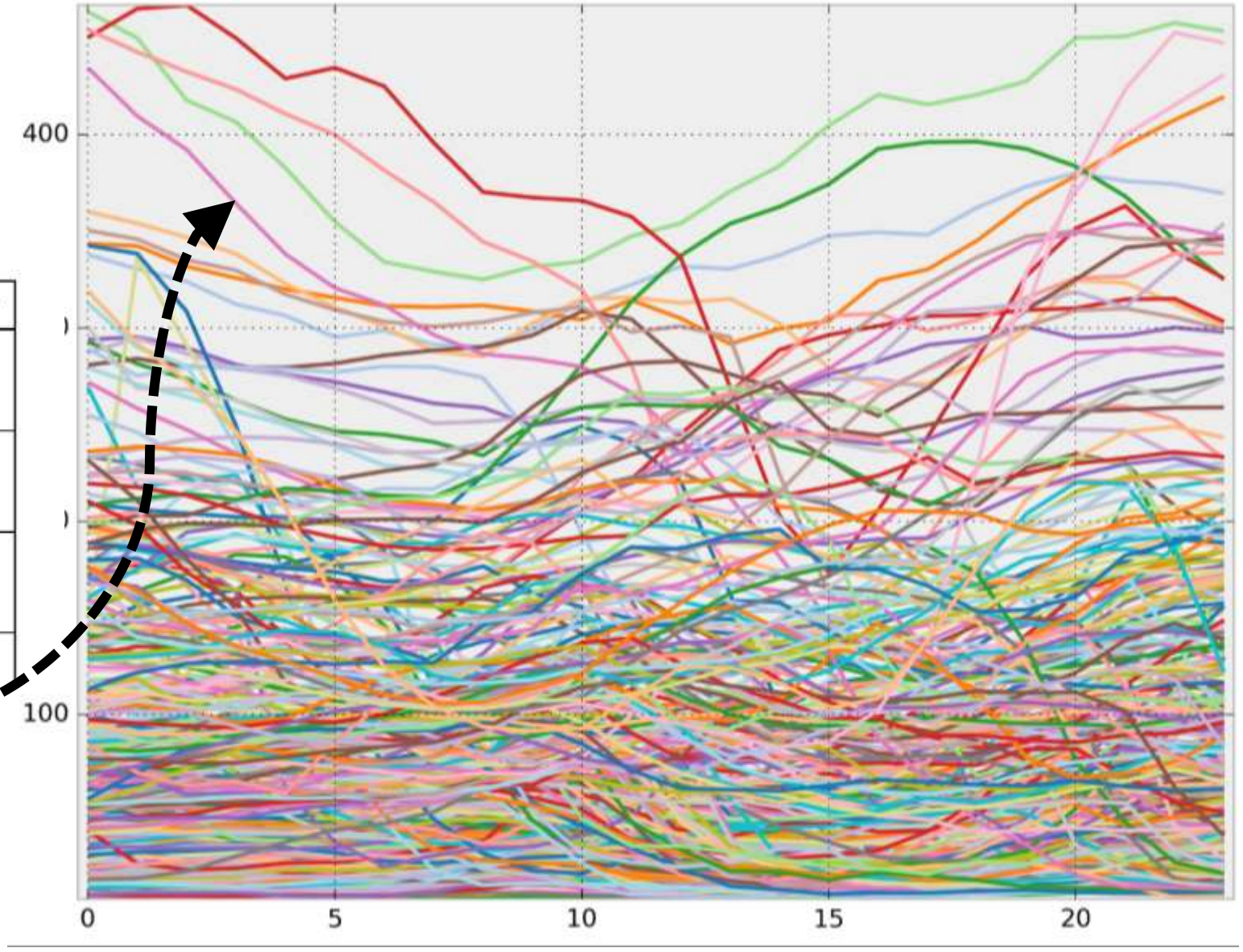


In the end, we have 365 time-series objects (lines) with 24 data points each to analyze.



January 2014

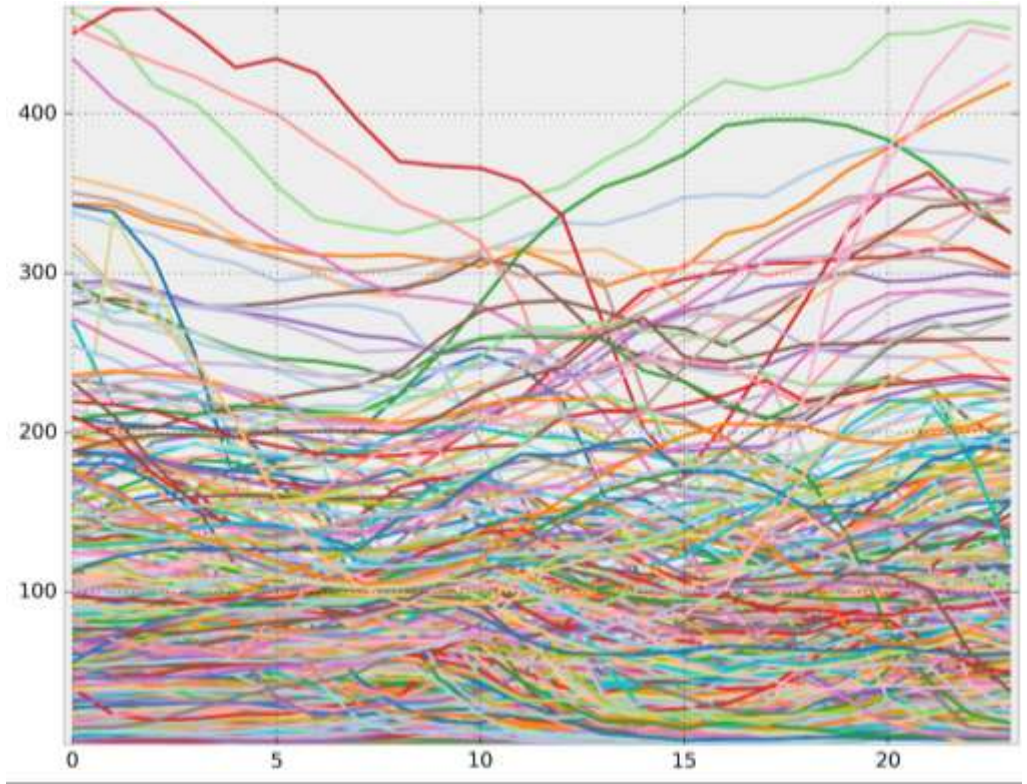
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25

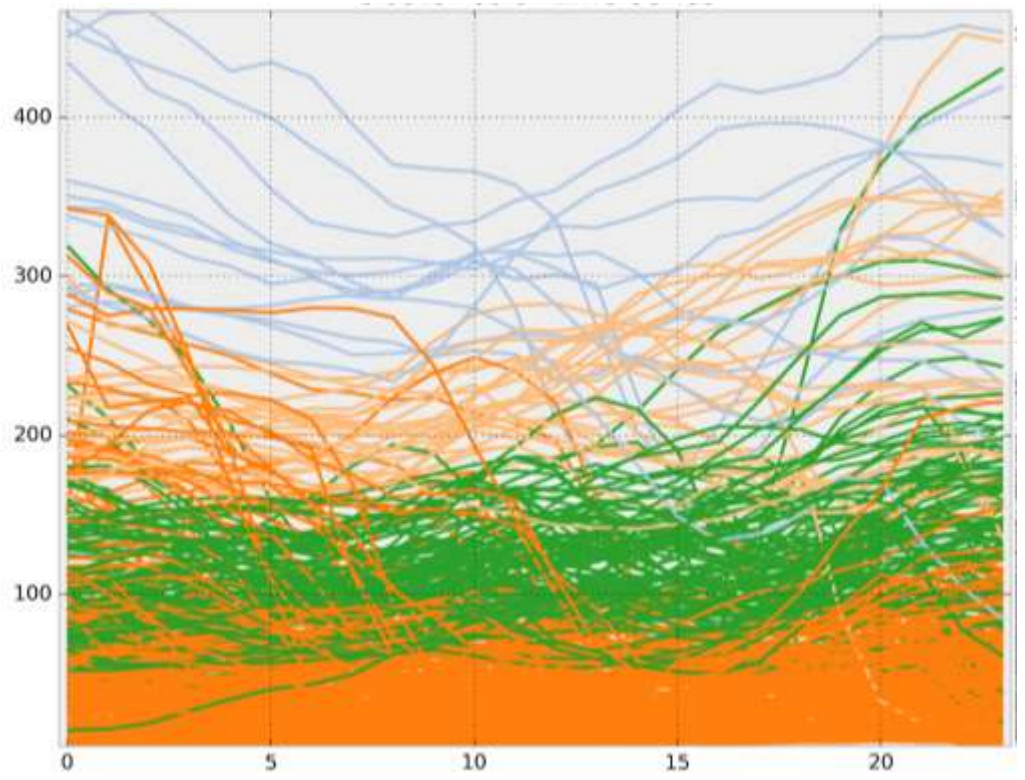


To let the data show its own pattern instead of imposing predefined time scale,

we need to aggregate together time-series objects with similar variation patterns of $PM_{2.5}$ concentration and

separate those with dissimilar time series into different groups

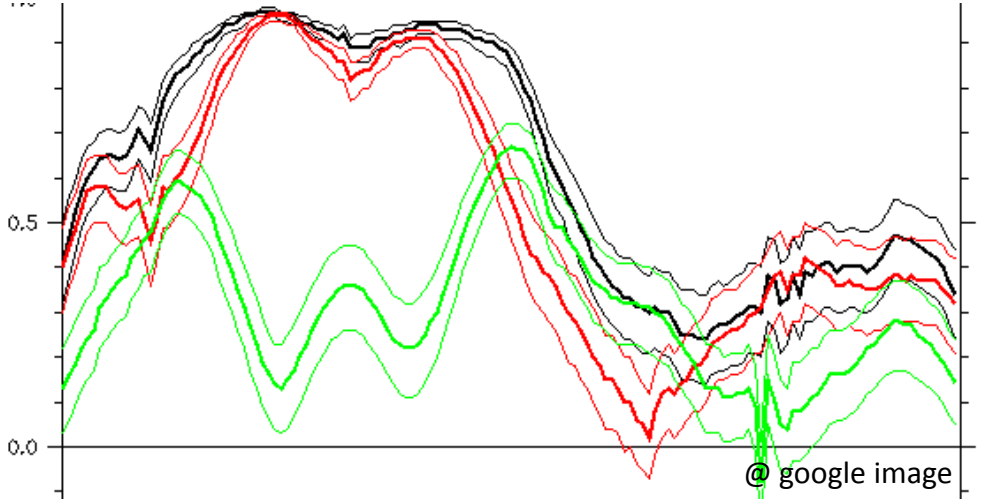




Cluster Analysis

- Average-linkage agglomerative hierarchical clustering
- We use Euclidean distance to identify the level difference between $PM_{2.5}$ time-series, Pearson's correlation-based distance to capture the shape difference between $PM_{2.5}$ time-series.

@ google image



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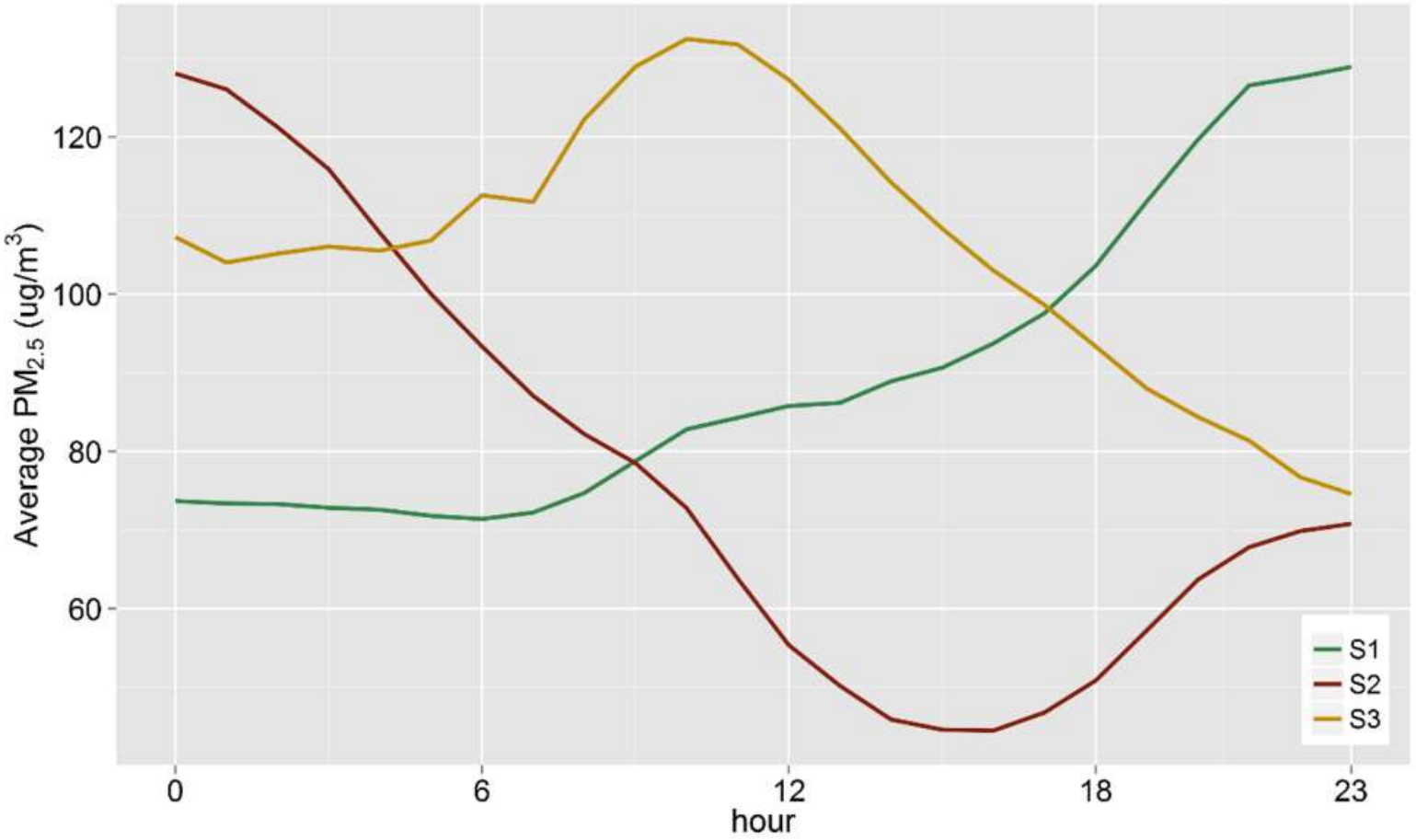
3 Result
研究結果

Cluster result based on shape/trend



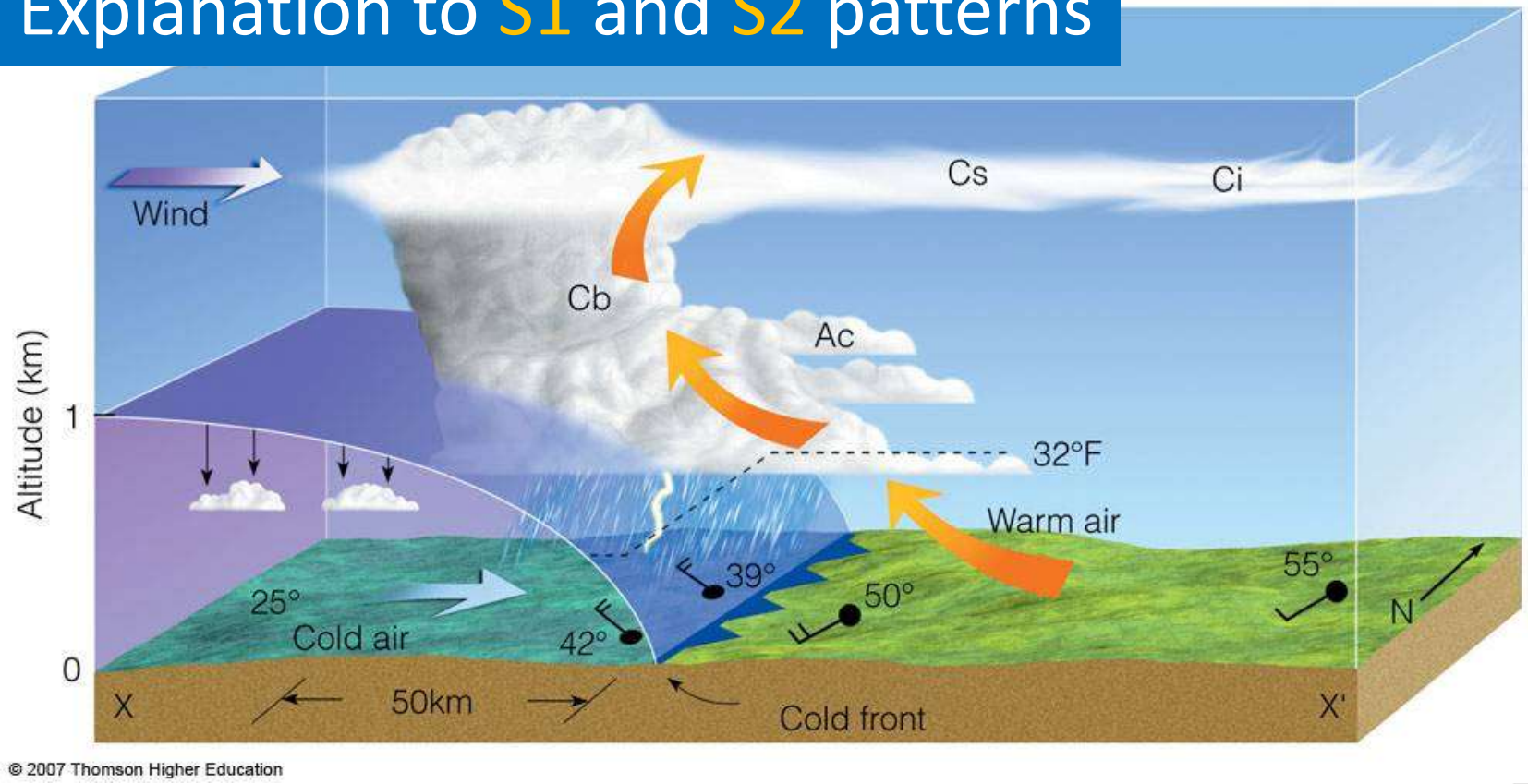
(Upper) the calendar plot based on shape difference

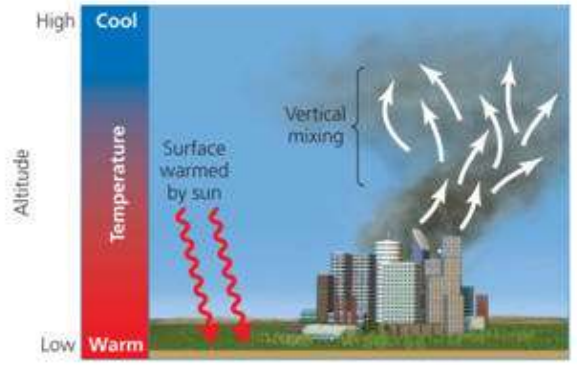
(Left) averaged $PM_{2.5}$ variation curve

Interpretation

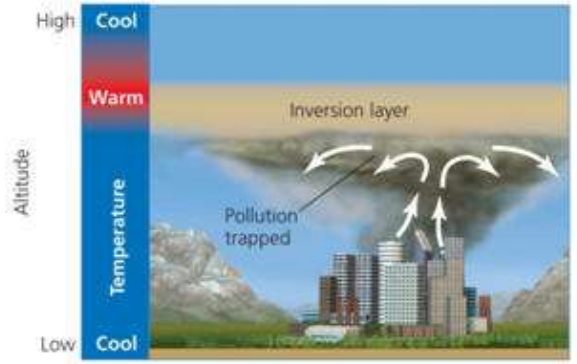
- **THREE** distinct variation patterns
- increasing pattern (S1) is most likely to be observed from January to March and from September to December. the maximum $PM_{2.5}$ concentration of the day usually occurs at night.
- decreasing pattern can be observed in all months throughout the year (S2) and this pattern attains its minimum value in the afternoon.
- an inverted V pattern often take place from April to August (S3) and the maximum $PM_{2.5}$ concentrations during these days usually peaks at noon.

Explanation to S1 and S2 patterns



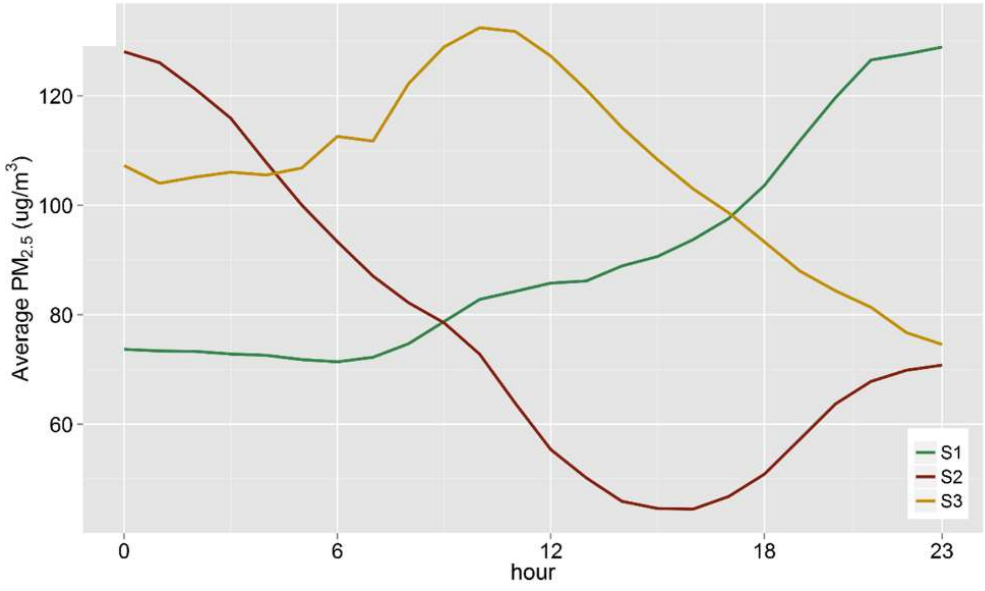


(a) Normal conditions



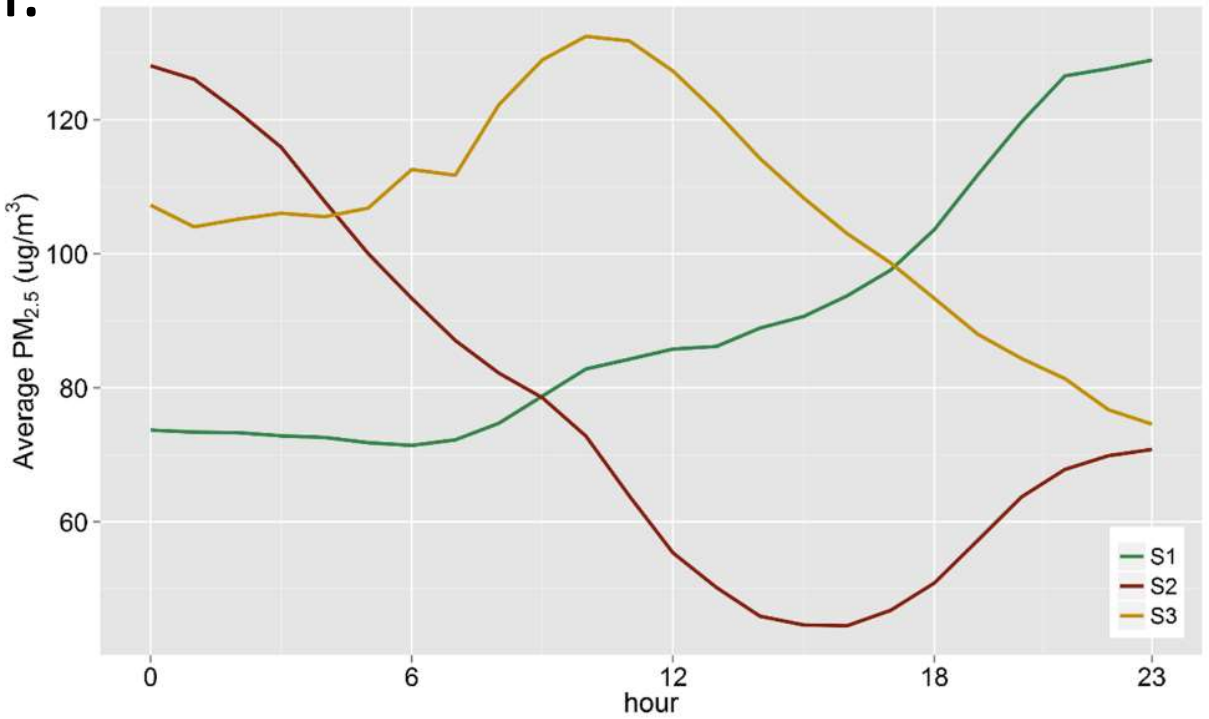
(b) Thermal inversion

When cold front arrives, high-speed wind associated with the cold front blows the pollution away and thus the $PM_{2.5}$ is decreasing; when cold front moves on, the $PM_{2.5}$ increases due to temperature inversion.



Explanation to S3 pattern

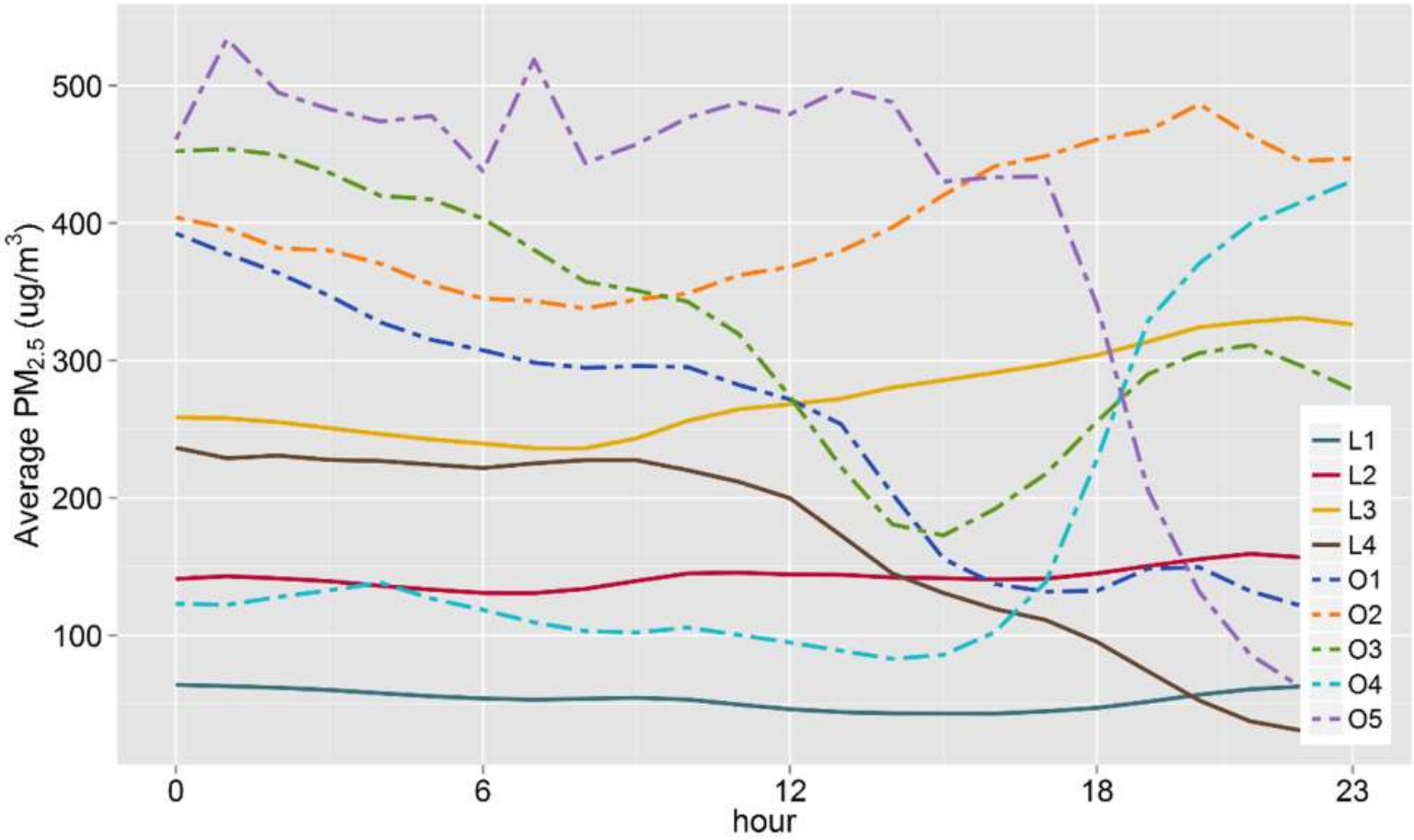
- S3 variation patterns in $PM_{2.5}$ concentration match human activities that usually peaks in the morning and afternoon during a full day.
- suggests from April to August (Summer), the weather conditions (e.g., cold front) weaken and human activities thus might have stronger impact on $PM_{2.5}$ variation.



Cluster result based on level difference

(Upper) the calendar plot based on level difference

(Left) averaged curve



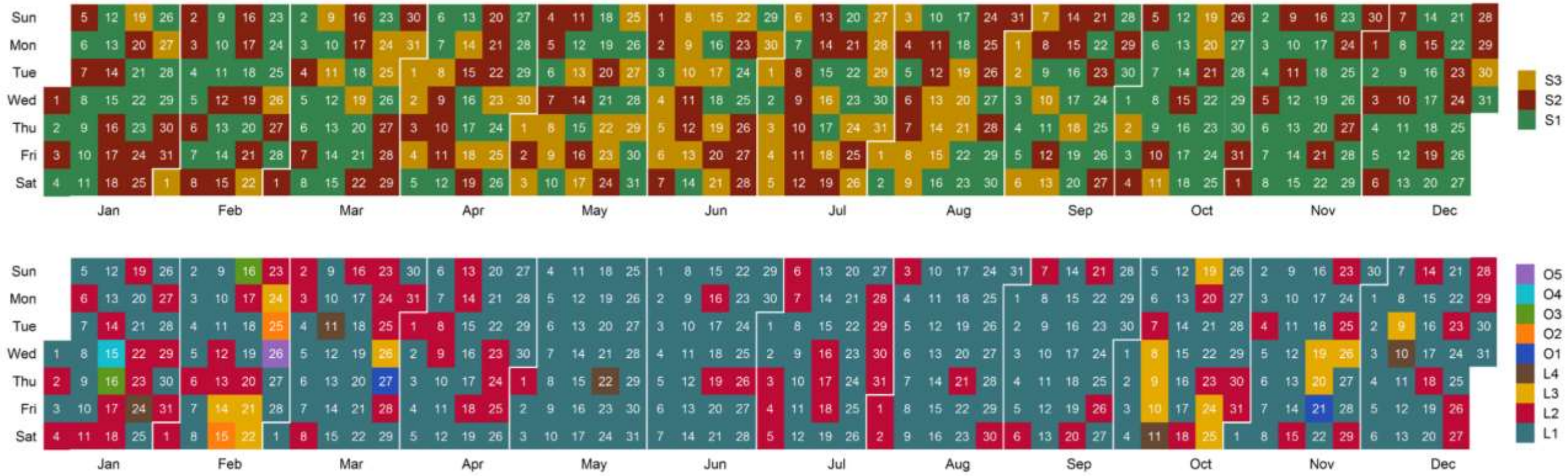
Interpretation

- A majority of days in the year have an averaged $PM_{2.5}$ concentration of ~50 µg/m^3 (L1 in Fig. 2b and Fig. 2d), a figure far from the WHO (25 µg/m^3) and USA air quality standards (15 µg/m^3).
- high averaged $PM_{2.5}$ concentration around 150 µg/m3 (L2 in Fig. 2b and Fig. 2d) are likely to occur in every month throughout the year.

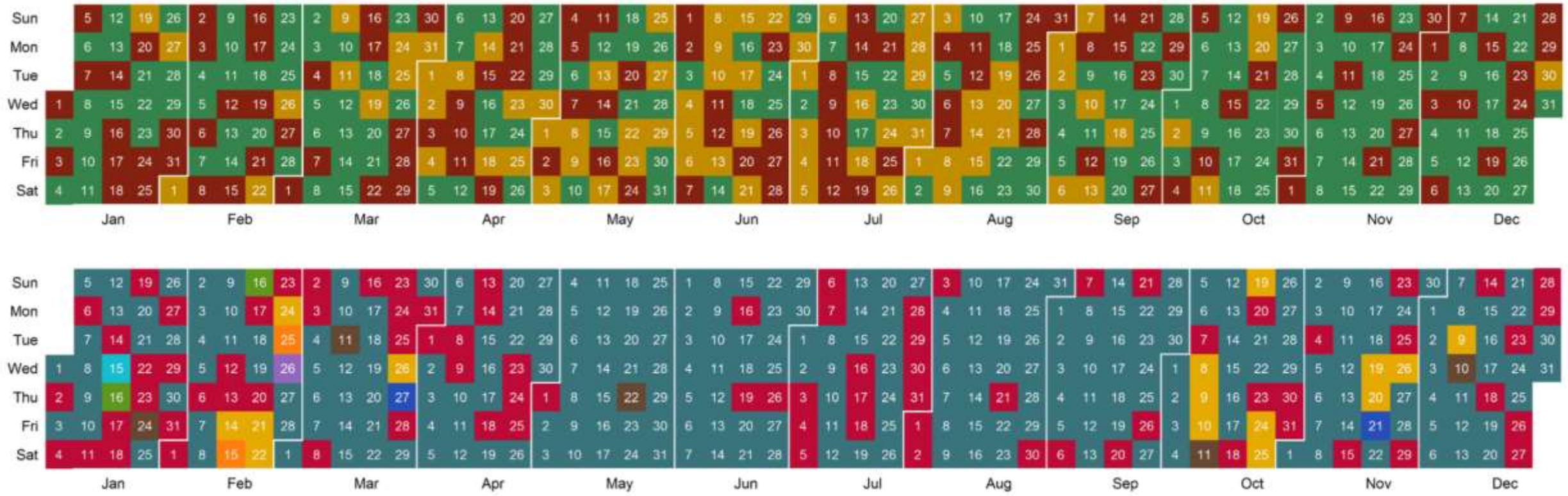
Interpretation

- Extremely high $PM_{2.5}$ concentration above 250 µg/m^3 (L3, O1, O2, O3, O4, and O5) can be usually observed in January, February, March, October, November, and December.
- This finding is consistent with previous studies in that $PM_{2.5}$ concentration is generally the highest during winter and lowest during summer (Wang, Ying et al. 2014, Zhang and Cao 2015).

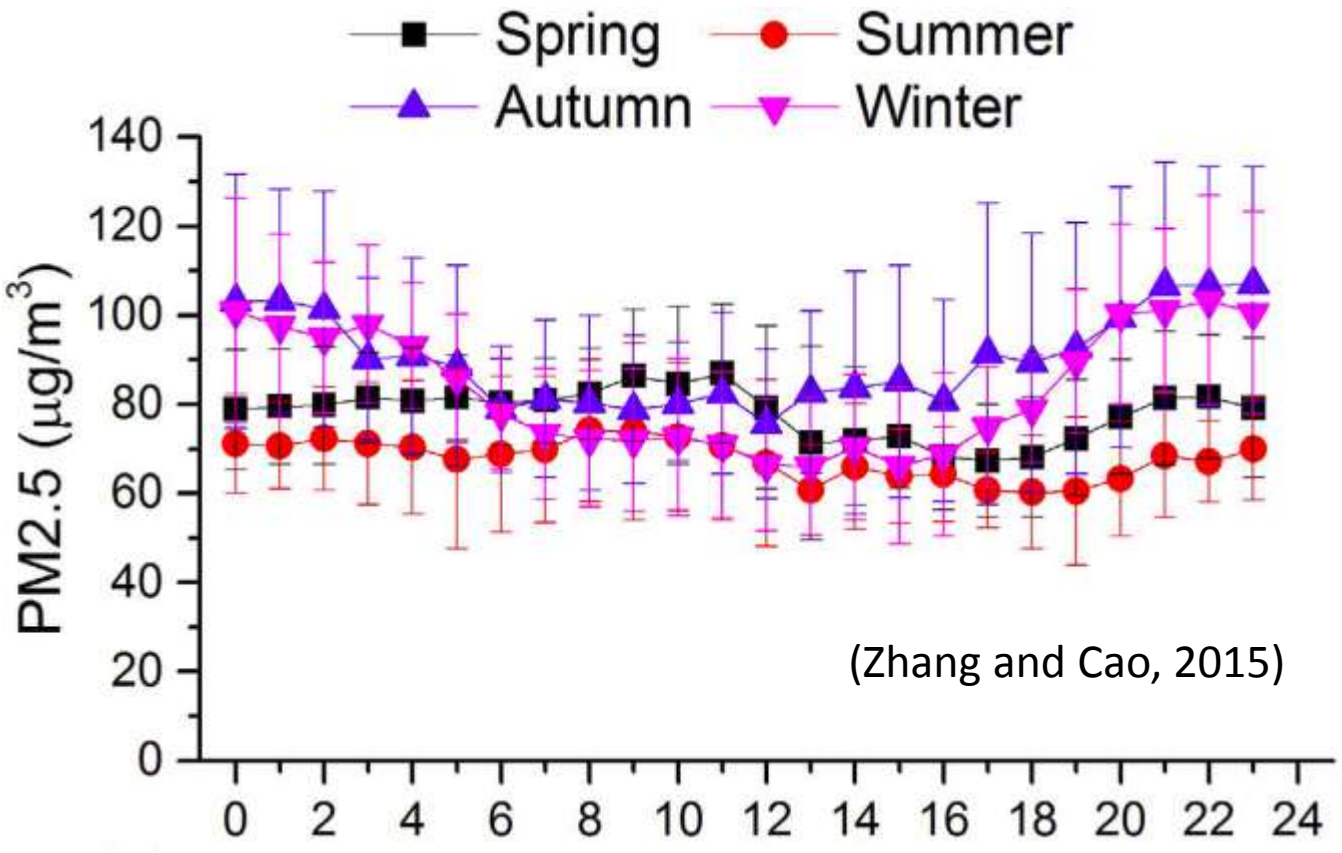
Are there seasonal and weekly patterns?



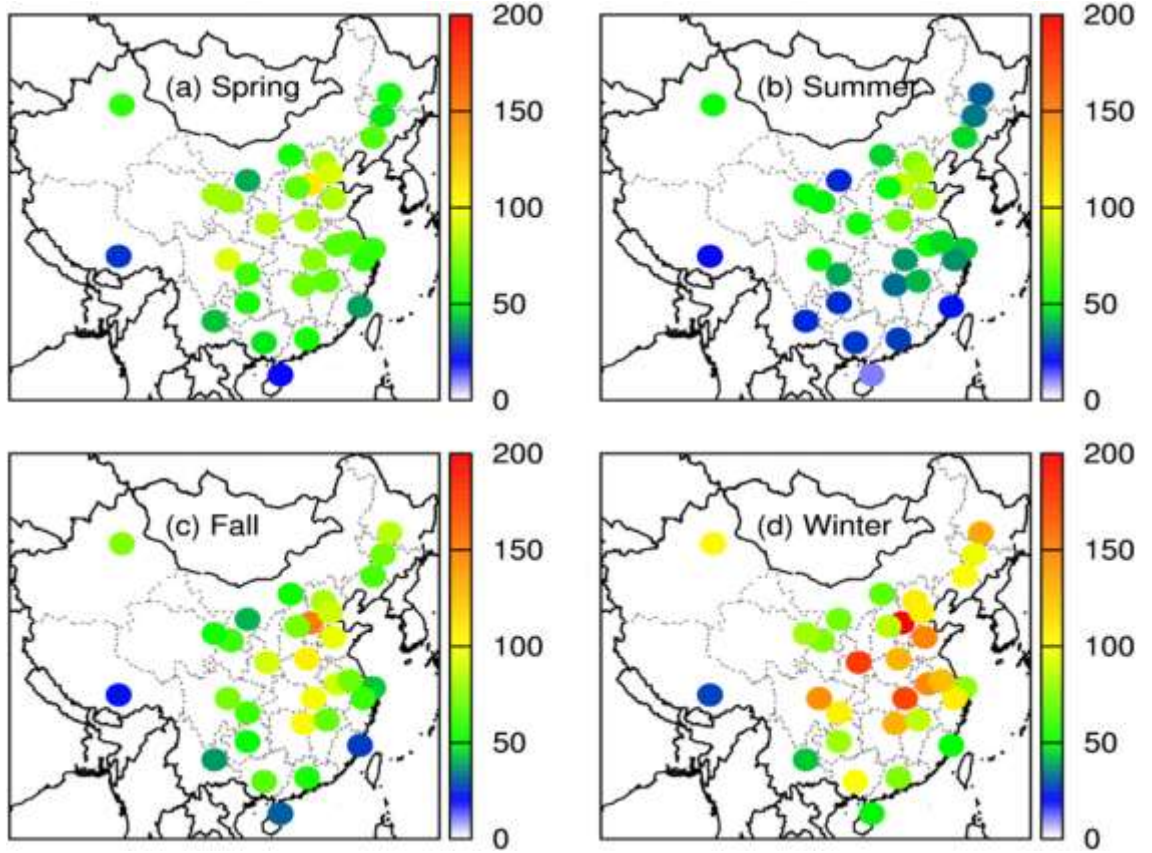
Seasonal patterns exist but they do not follow a strict temporal division.



No universal weekly variation pattern in $PM_{2.5}$ concentration.

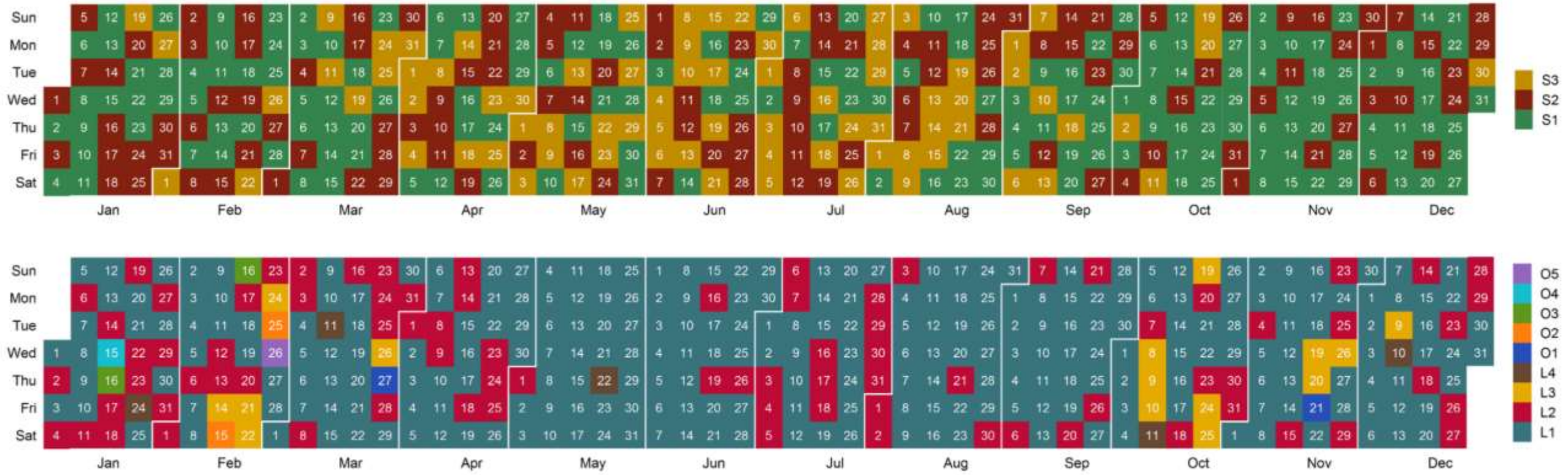


(Zhang and Cao, 2015)



(Wang et al., 2014)

the arbitrary seasonal division of variation in $PM_{2.5}$ concentration may result in information loss and conceal potentially important insights.



Our study provides an informative and straightforward calendar visualization to look into $PM_{2.5}$ pattern.

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4 Summary
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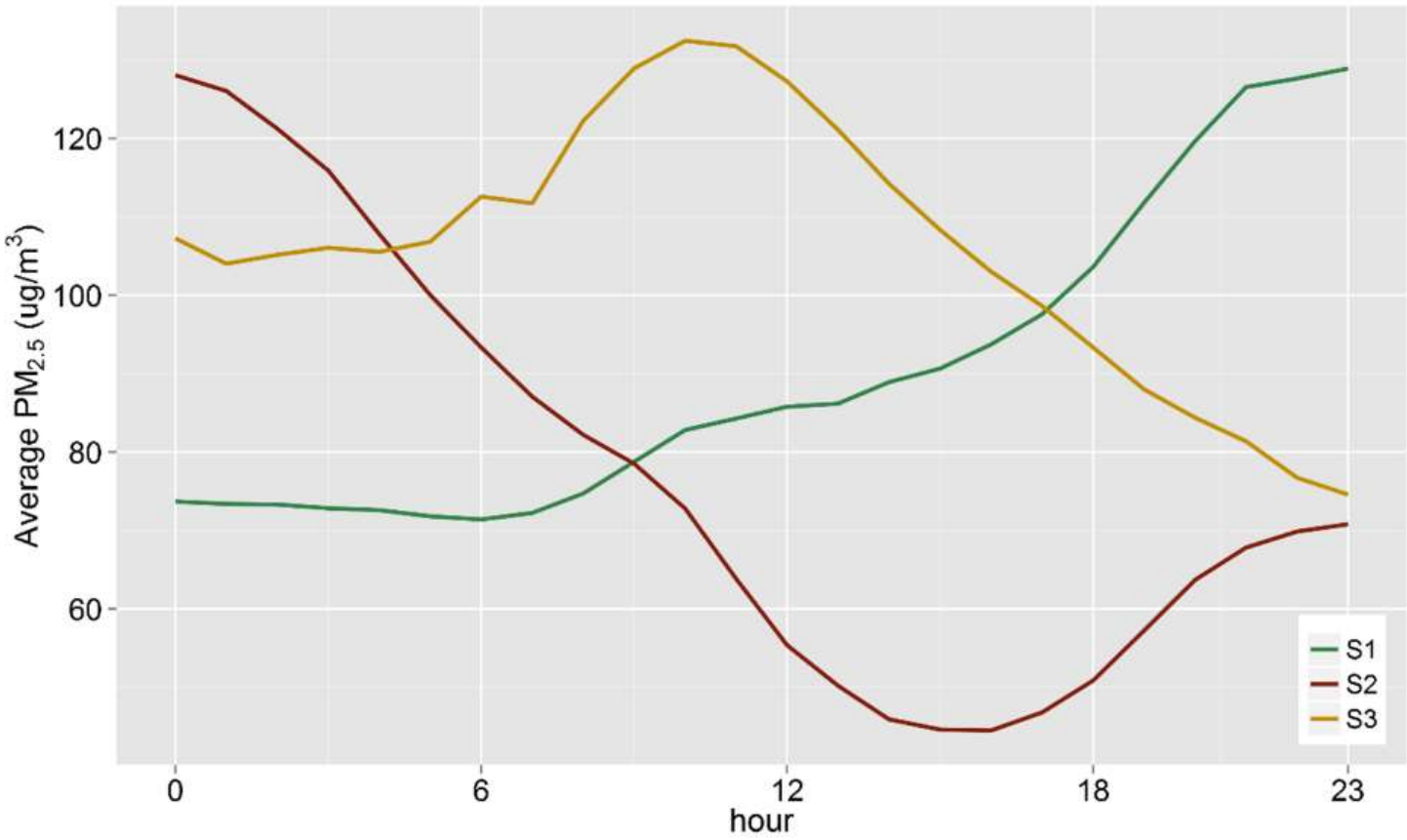
Contribution

- Offer an innovative and straightforward calendar visualization of daily $PM_{2.5}$ concentration time-series in Beijing;
- Yields intuitive insights and Advance our understanding on Beijing's $PM_{2.5}$ concentration;
- Brings in unique perspective and convincing detailed insights on $PM_{2.5}$ concentration.

Take-home Message 關鍵信息

- There are three distinct diurnal variation patterns for the $PM_{2.5}$ time-series.



Take-home Message 關鍵信息

- No weekly patterns; seasonal patterns exist but they do not follow a strict temporal division.

Take-home Message 關鍵信息

- A majority of days in the year have an averaged $PM_{2.5}$ concentration of around 50 μg/m^3, a figure far from the WHO (25 μg/m^3) and USA air quality standards (15 μg/m^3).

Take-home Message 關鍵信息

- High averaged $PM_{2.5}$ concentration around 150 μg/m^3 (L2 in Fig. 2b and Fig. 2d) are likely to occur in every month throughout the year.

Thank you!

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