Spatiotemporal variability patterns of $PM_{2.5}$ in severe pollution events based on a large dataset from air quality monitoring stations over South Korea

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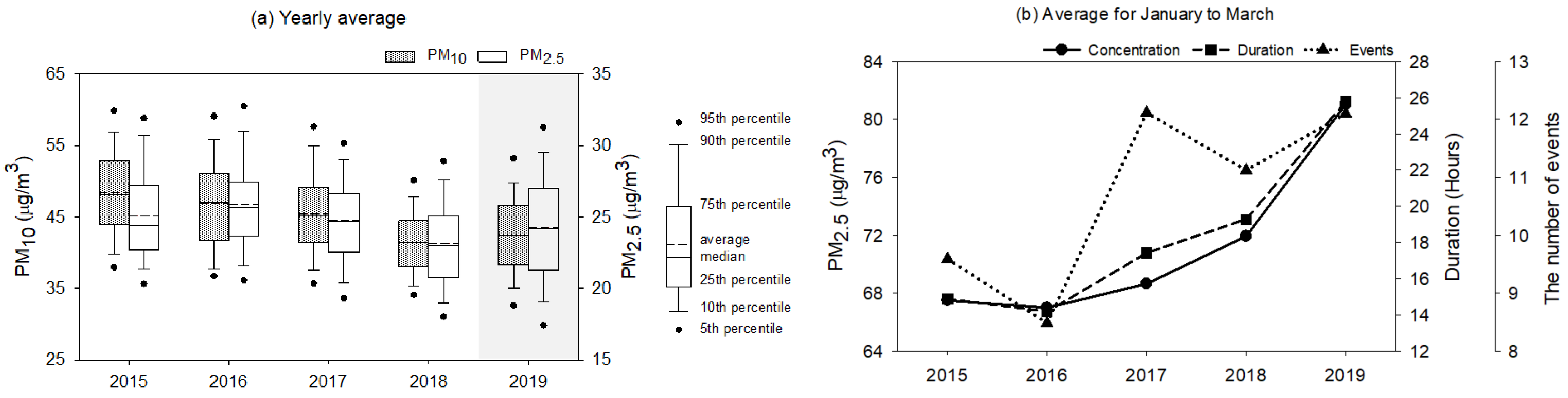
Introduction

- East Asia (i.e. Korea, China, and Japan) has suffered from severe air pollution every year concerning particulate matter less than 2.5㎛ in diameter ($PM_{2.5}$).



- Annual PM average from 2015 to 2018 was decreasing rate (Fig. a).
- However, more frequent $PM_{2.5}$ events with greater intensity and longer duration contribute at least partially to higher mean PM concentrations for the spring seasons (January to March) (Fig. b).

Introduction

- Ambient $PM_{2.5}$ has longer residence time (i.e. days to weeks) because it neither settles nor coagulates quickly. Therefore, $PM_{2.5}$ is capable to transport to distant region.

- Therefore, analysis limited to narrow region may miss the flow of $PM_{2.5}$ associated with synoptic weather conditions. This means a wide range of comprehension not only regional growth of $PM_{2.5}$ concentrations but also the inflow of $PM_{2.5}$ from the surrounding areas is needed.

- We attempted to find statistically how the magnitude and duration of high $PM_{2.5}$ pollution over Korea distributed with a focus on spatiotemporal variations and categorized the characteristic patterns of events based on COD results.

- We also represented time-lag distributions with synoptic weather conditions, and we suggested the relationship between high $PM_{2.5}$ pollution events and weather condition considering time-lag corrected COD and R^2 results.

Method

1. Data

- Hourly $PM_{2.5}$ concentration data
- 381 air quality monitoring stations (AQMS) in Korea
- January 1, 2015–September 30, 2019

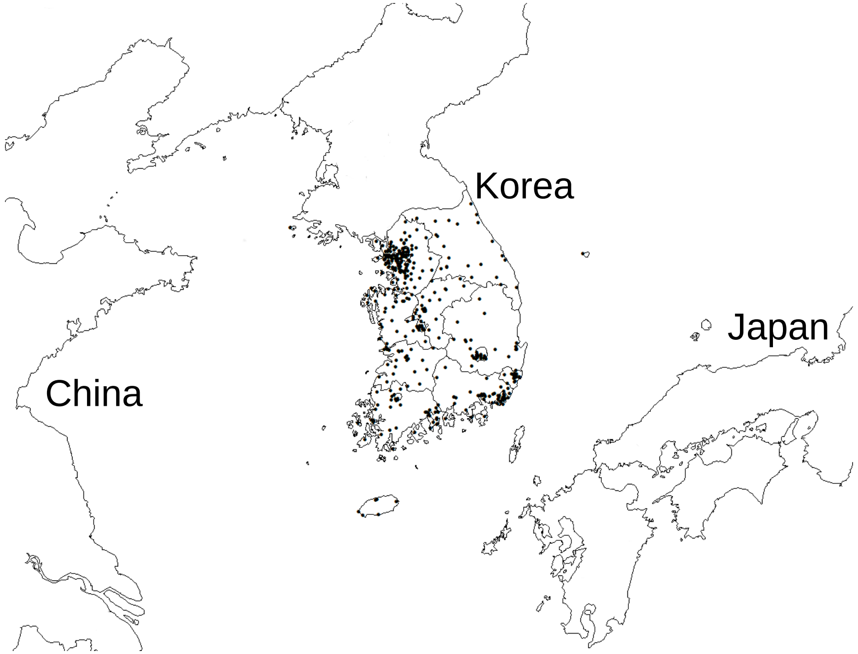


Figure 1. AQMS sites

2. High $PM_{2.5}$ pollution events

- We defined high $PM_{2.5}$ pollution period in a basis of watch alert standard in Korea for which hourly $PM_{2.5}$ concentration exceeds **75 ㎍/㎥** for at least two hours

3. Spatiotemporal variability

- Two statistical methods (Time-lag correlation and Coefficient of divergence) were used to see spatiotemporal heterogeneity

- Time-lag correlation

- calculates the different response time between a pair of sites

$$r = \frac{1}{T\sigma_a\sigma_b}\int_{t_0}^{t_0+T}(a(t)-\bar{a})\left(b(t+\tau)-\bar{b}\right)\mathrm{dt}$$

a, b : simultaneously measured species
t : time
τ : a time-lag applied to time series in b
σ : standard deviation for the pollutants a and b
T : the number of data points

(Choi et al., 2012)

- Coefficient of divergence (COD)

- determines the divergence degree between a pair of sites

$$COD = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{x_{if}-x_{ih}}{x_{if}+x_{ih}}\right)^2}$$

x_{if}, x_{ih} : the concentrations of one species for the ith time period at sites f and h, respectively.
n : the number of observations
COD Value ≈ 0 : totally homogeneous
COD Value > 0.2 : heterogeneously distributed

(Wilson et al., 2005)

Result

1. Spatiotemporal distribution of $PM_{2.5}$ for the high pollution events

- We examined the spatial distributions of $PM_{2.5}$ for pollution periods using COD and the coefficient of determination (R^2) values calculated with a pair of time-series of $PM_{2.5}$ between the reference site (averaged for 25 AQMS in Seoul) and other monitoring sites

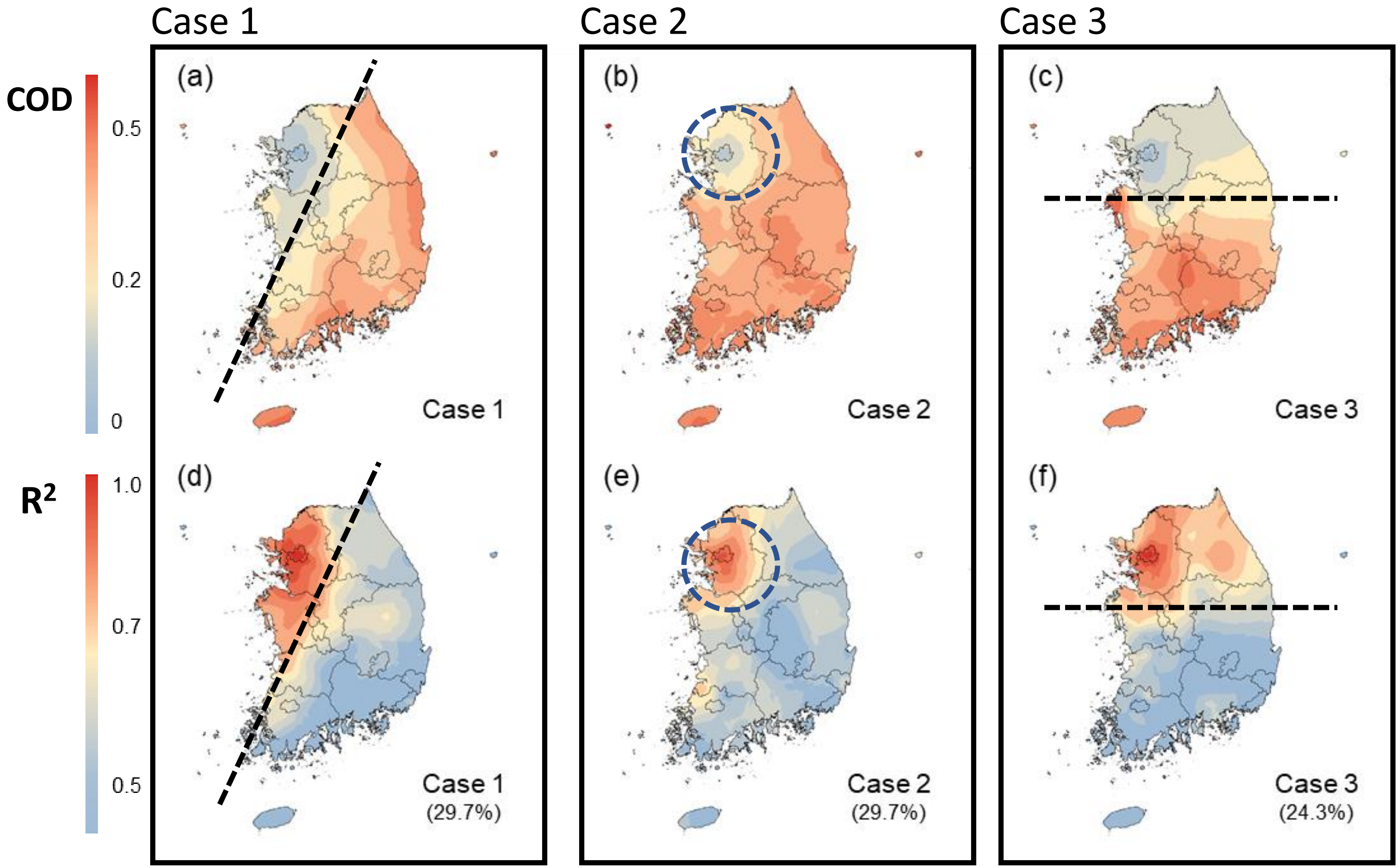
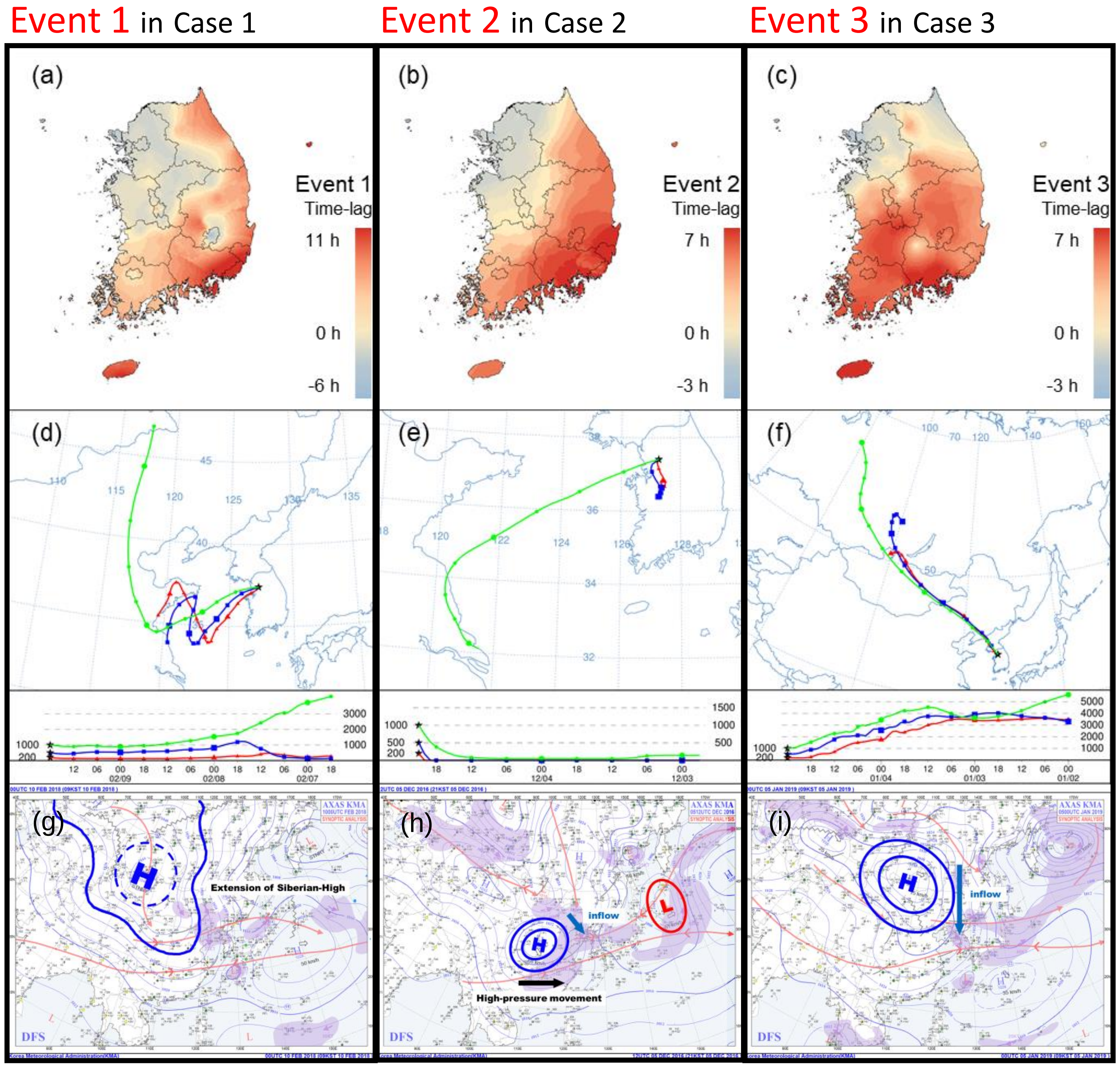


Fig. Categorized COD and R squared distributions

- The case I, case II, and case III represent 11 events (29.7%), 11 events (29.7%), and 9 events (24.3%) of 37 events in total, respectively.
- COD and R^2 values in three high $PM_{2.5}$ cases showed characteristic distribution patterns.
- Both COD and R^2 showed distinct boundaries (showed by dotted line) of heterogeneity and similarity.

Result

2. Time-lag distribution of $PM_{2.5}$ for the high pollution events and corresponding air mass back-trajectory



- This figure shows three representative time-lag distribution and synoptic weather condition for high $PM_{2.5}$ events of each categorized case.
- Backward trajectory was analyzed using the NOAA HYSPLIT model to evaluate pollutant transportation pathway, and ground level weather maps which represent the pressure distribution from KMA were also analyzed.
- Expansion of Siberian high caused westerly inflow of air mass in Event 1, pollutants with stagnant high-pressure was slowly moved to eastward in Event 2, and anticyclone stayed over Manchuria made downward inflow in Event 3.
- The air mass inflow with the air pressure distribution well expressed time-lag distribution. This means time-lag distributions were highly related with the synoptic weather condition in high $PM_{2.5}$ events.

Result

3. Time-lag corrected distributions of $PM_{2.5}$ for high $PM_{2.5}$ events

▸ We modified the time considering the time-lag of each site and obtained time corrected COD and R squared values

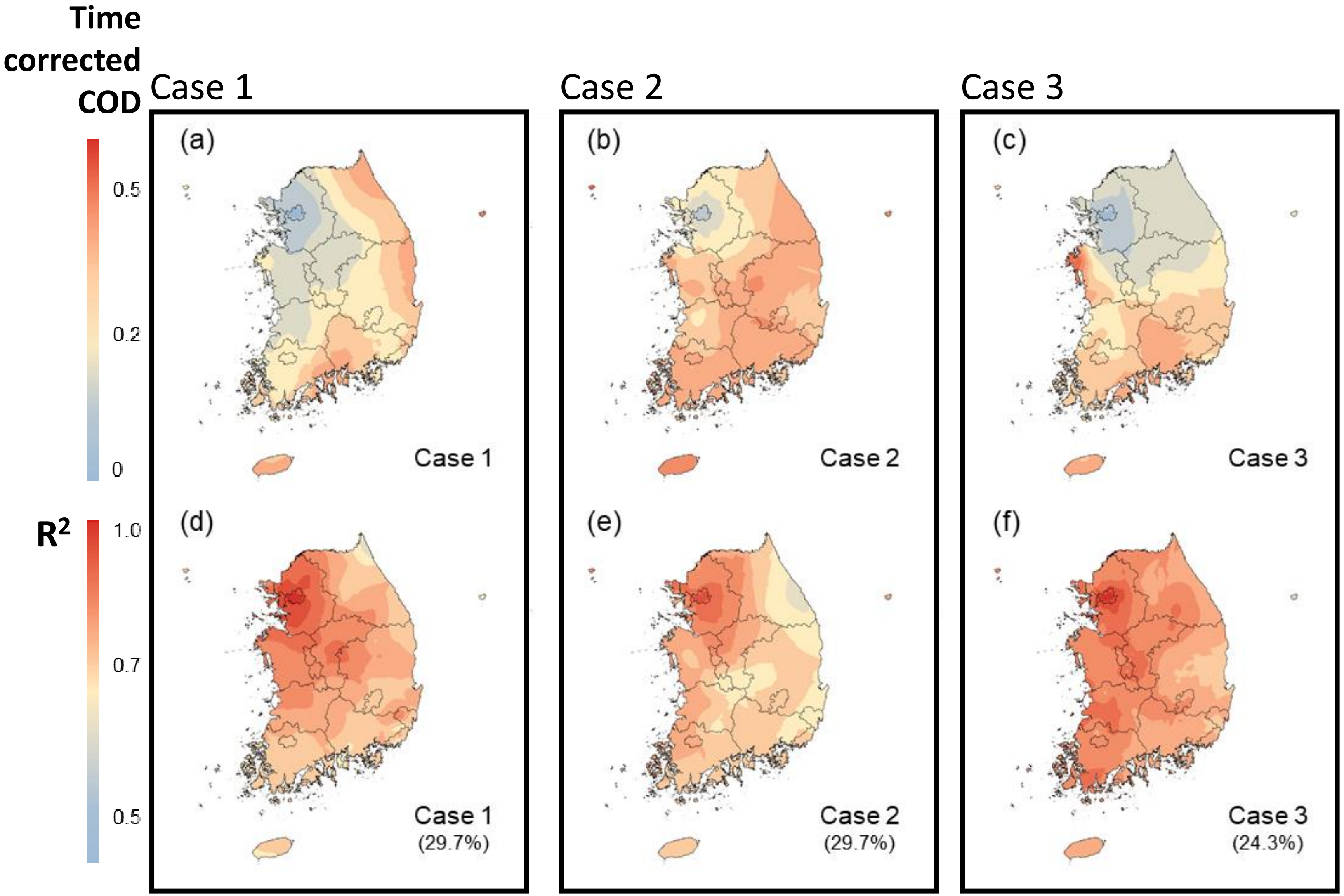


Fig. Time-lag corrected COD and R squared distributions

▸ Time corrected COD showed wider homogeneous distribution with a slightly improve in most region but did not decrease noticeably.

▸ This can be explained by the absolute difference in concentration magnitude of each site.

▸ However, time corrected R^2 represented homogeneous over Korea. This means high PM2.5 events was highly related to the movement of air mass.

Conclusion

- Time-lag correlation and COD results showed characteristic variability patterns.
- COD and R squared values showed characteristic distributions,
- Time-lag distributions in high $PM_{2.5}$ events were related with air mass movement.
- Time-lag corrected COD values were slightly improved, and R^2 represented strong similarity in variability of $PM_{2.5}$ concentration.
- These results imply that high $PM_{2.5}$ events are mainly affected by synoptic weather condition.

Reference

W. Choi et al. (2012), *Atmospheric Environment*, **62**:318-327.

Wilson et al. (2005), *Atmospheric Environment*, **39**:6444-6462.

Acknowledgment

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Thank you

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