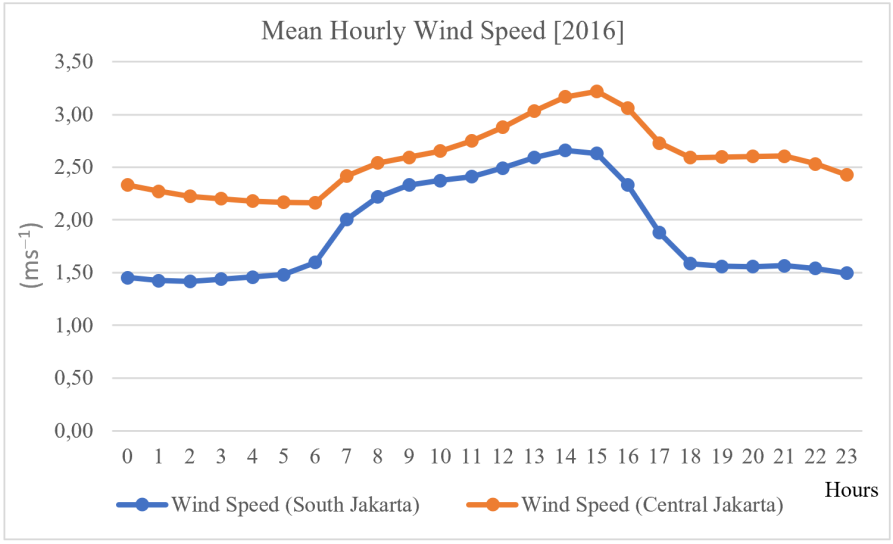
Supplementary



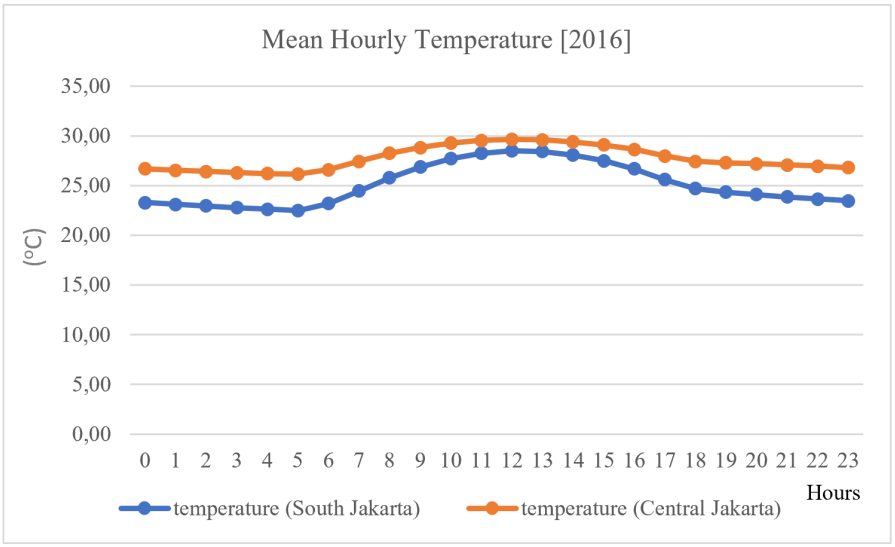


Fig. S1. Mean hourly temperature and wind speed in Central Jakarta and South Jakarta

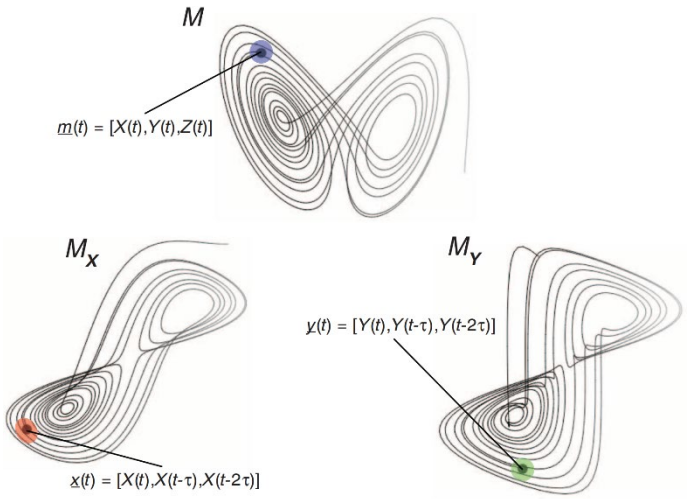
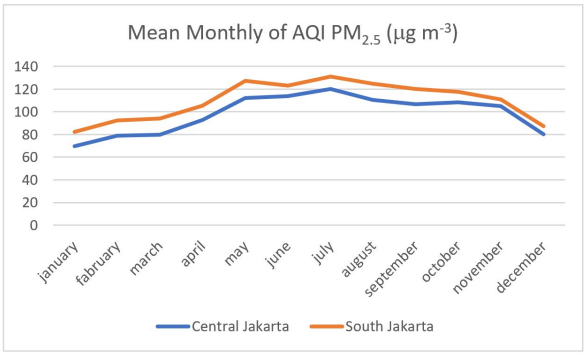
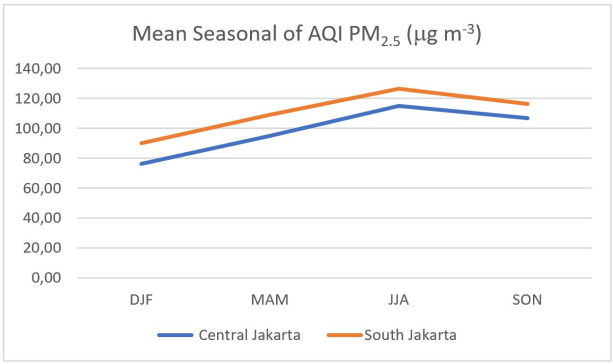


Fig. S2. Convergent cross mapping test for correspondence between shadow manifolds (Tsonis et al., 2018)

According to Aldrian & Dwi Susanto (2003), seasons in Indonesia are affected by the monsoon activity. The seasons in Indonesia can be divided into four groups, such as December–January–February (DJF), March–April–May (MAM), June–July–August (JJA), and September–October–November (SON) seasons. DJF season represents the peak of the northwest Australia–Asia monsoon, JJA season represents the peak of the southeast Australia–Asia monsoon, and both MAM and SON seasons represent monsoon transitions. Supari *et al.* (2017) explained that the wetting trends of several extreme precipitation were prominent in December–January–February (DJF) and/or March–April–May (MAM) seasons.





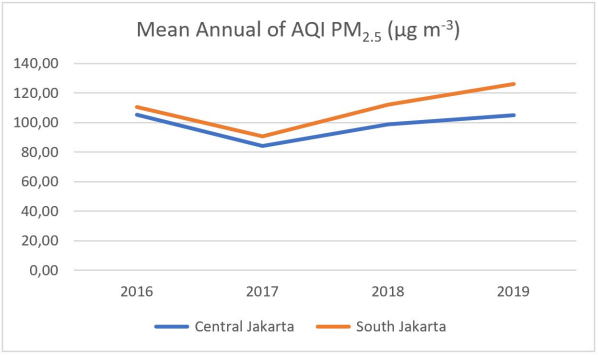


Fig. S3. Mean monthly, seasonal, and annual AQI of $PM_{2.5}$ in Central Jakarta and South Jakarta

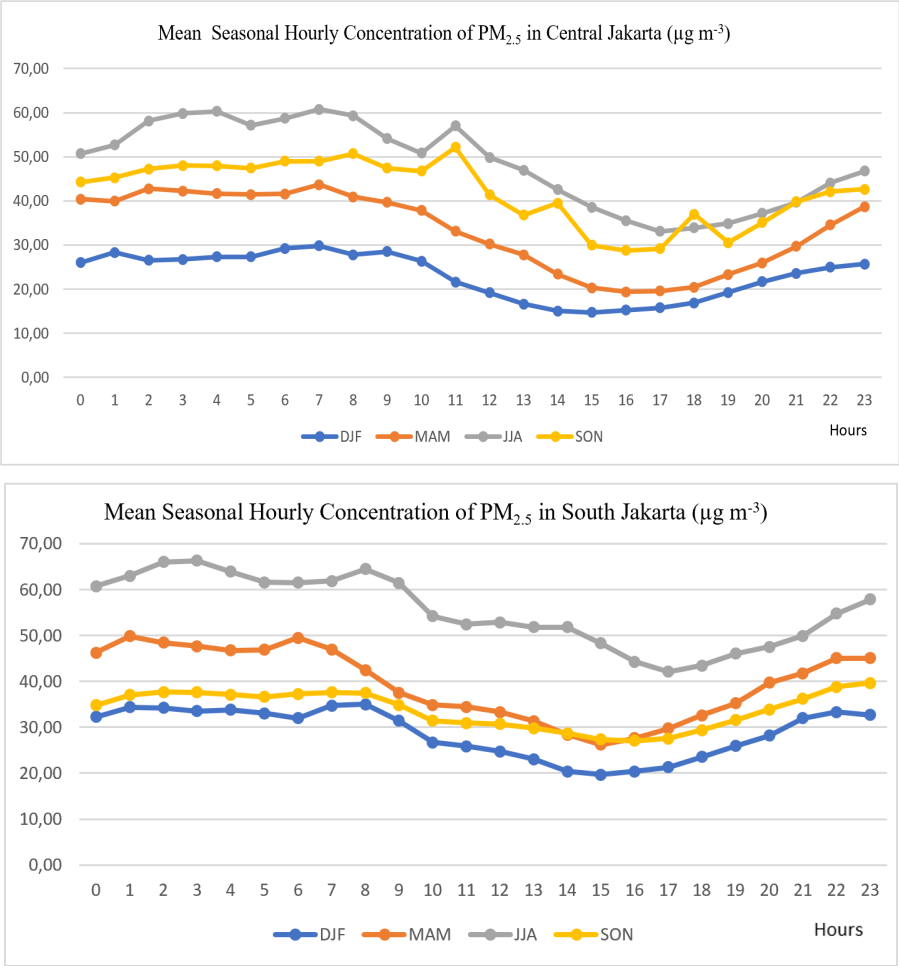


Fig. S4. Mean hourly $PM_{2.5}$ concentration based on the seasonal variation

Table S1. Previous reports on causality analysis using CCM method to determine the relationship between meteorological parameters with local $PM_{2.5}$ concentration.

Reference	Results	Location	Location's Characteristics	Type of Data
Zou *et al*., 2021	Identified the nonlinear coupling patterns in various seasons	Xining Tibet	Rural area and plateau area	Daily Data
Chen *et al*., 2017	Determined mirage correlation using the correlation between individual meteorological parameters and local $PM_{2.5}$ concentration	Jing-Jin-Ji Region, China	Urban area, megacity area, and low-altitude area	Daily Data
Chen *et al*., 2018	Identified how individual meteorological parameters affects local $PM_{2.5}$ concentration in different locations and seasons	Mainland China (37 representative cities)	Urban area and megacity area	Hourly Data
Chen *et al*., 2020	Made a comprehensive review on the impacts of meteorological parameters to the concentration of $PM_{2.5}$ using causality analysis which was concluded to be better than other methods	All China Region	Urban area and megacity	Daily Data
Chelani, 2017	Conducted research on how the similarity dan causality analysis can be used to identify the effects of nonlocal $PM_{2.5}$	New Delhi, India	Urban area, megacity area, and low-altitude area	Hourly Data
Yao, 2017	Identified that causal effect of $PM_{2.5}$ concentration on the evapotranspiration	Jing-Jin-Ji Region, China	Urban area, megacity area, and low-altitude area	Daily Data

Table S2. Nonlinear coupling relationship of air quality parameters and $PM_{2.5}$ concentrations based on seasonal variations using KG, LB, and KJ sensors

Seasonal Variation	City Area	Causality	PM_{10}(KG)	SO_2 (KG)	CO (KG)	O_3 (KG)	NO_2 (KG)	PM_{10} (LB)	SO_2 (LB)	CO (LB)	O_3 (LB)	NO_2 (LB)
DJF	Central Jakarta	$\hat{X}\|My$	0,61	0,56	0,36	0,42	0,61	0,56	0,34	0,4	0,45	0,43
		$\hat{Y}\|Mx$	0,7	0,26	0,36	0,21	0,7	0,36	0,03	0,14	0,24	0,25
	South Jakarta	$\hat{X}\|My$	0,64	0,64	0,23	0,4	0,64	0,65	0,46	0,49	0,44	0,42
		$\hat{Y}\|Mx$	0,71	0,37	0,28	0,24	0,71	0,6	0,2	0,25	0,34	0,38
MAM	Central Jakarta	$\hat{X}\|My$	0,74	0,46	0,36	0,4	0,74	0,65	0,6	0,35	0,25	0,51
		$\hat{Y}\|Mx$	0,74	0,05	0,15	0,19	0,74	0,66	-0,01	0,2	0,3	0,28
	South Jakarta	$\hat{X}\|My$	0,69	0,47	0,34	0,4	0,69	0,65	0,68	0,41	0,28	0,55
		$\hat{Y}\|Mx$	0,65	0,22	0,19	0,03	0,65	0,62	0,15	0,15	0,28	0,31
JJA	Central Jakarta	$\hat{X}\|My$	0,54	0,56	0,3	0,48	0,54	0,2	0,65	0,39	0,35	0,55
		$\hat{Y}\|Mx$	0,47	0,29	0,21	-0,03	0,47	0,19	0,56	0,2	0,28	0,41
	South Jakarta	$\hat{X}\|My$	0,61	0,46	0,35	0,45	0,61	0,36	0,6	0,39	0,41	0,41
		$\hat{Y}\|Mx$	0,54	0,29	0,27	0,28	0,54	0,33	0,21	0,23	0,18	0,33
SON	Central Jakarta	$\hat{X}\|My$	0,54	0,46	0,2	0,34	0,54	0,45	0,44	0,17	0,24	0,32
		$\hat{Y}\|Mx$	0,55	0,21	0,1	0,12	0,55	0,39	0,24	0,19	0,16	0,14
	South Jakarta	$\hat{X}\|My$	0,73	0,66	0,19	0,45	0,73	0,52	0,57	0,27	0,38	0,31
		$\hat{Y}\|Mx$	0,69	0,38	0,1	0,24	0,69	0,38	0,01	0,08	0,36	0,11

Seasonal Variation	City Area	Causality	PM_{10}(KJ)	SO_2 (KJ)	CO (KJ)	O_3 (KJ)	NO_2 (KJ)
DJF	Central	$\hat{X}\|My$	0,45	0,37	0,38	0,3	0,48
	Jakarta	$\hat{Y}\|Mx$	0,41	-0,01	0,2	0,36	0,37
	South	$\hat{X}\|My$	0,23	0,3	0,34	0,23	0,4
	Jakarta	$\hat{Y}\|Mx$	0,42	0,27	0,2	0,21	0,15
MAM	Central	$\hat{X}\|My$	0,71	0,4	0,19	0,31	0,52
	Jakarta	$\hat{Y}\|Mx$	0,57	0,03	0,19	0,34	0,12
	South	$\hat{X}\|My$	0,72	0,43	0,2	0,42	0,43
	Jakarta	$\hat{Y}\|Mx$	0,65	0,2	0,12	0,31	0,13
JJA	Central	$\hat{X}\|My$	0,57	0,52	0,52	0,28	0,3
	Jakarta	$\hat{Y}\|Mx$	0,46	0,1	0,04	0,31	0,11
	South	$\hat{X}\|My$	0,67	0,45	0,58	0,35	0,38
	Jakarta	$\hat{Y}\|Mx$	0,68	0,32	0,26	0,41	0,21
SON	Central	$\hat{X}\|My$	0,51	0,41	0,3	0,35	0,32
	Jakarta	$\hat{Y}\|Mx$	0,41	0,29	0,21	0,3	0,06
	South	$\hat{X}\|My$	0,59	0,48	0,45	0,54	0,28
	Jakarta	$\hat{Y}\|Mx$	0,56	0,23	0,34	0,33	0,07