The association between COVID-19 data and meteorological factors in Indonesia

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Abstract

On March 2, 2020, the first *Coronavirus Disease* (COVID-19) case was reported in Jakarta, Indonesia. One and half month later (15/05/2020), the cumulative number of infection cases was 16496 with a total of 1076 mortalities. This study is aimed to investigate the possible role of weather in the early cases of COVID-19 incidence in six selected cities in Indonesia. Daily data of temperature and relative humidity from weather stations nearby each city were collected during the period 3 March - 30 April 2020, together with data of COVID-19 cases. Correlation tests and regression analysis were performed to examine the association of those two data series. In addition, we analysed the distribution of COVID-19 with respect to weather data to estimate the effective range of weather data supporting COVID-19 incidence. Our results reveal that weather data is generally associated with COVID-19 incidence. The daily average temperature (T-ave) and relative humidity (RH) presents significant positive and negative correlation with COVID-19 data, respectively. However, the correlation coefficients are weak with the strongest correlations found at 5 day lag time i.e. 0.37 (-0.41) for T-ave (RH). The regression analysis consistently confirmed this relation. The distribution analysis reveals that the majority of COVID-19 cases in Indonesia occurred in the daily temperature range of 25-31°C and relative humidity of 74-92%. Our findings suggest that COVID-19 incidence in Indonesia has a weak association with weather conditions. Therefore, non-meteorological factors seem to play a larger role and should be given greater consideration in preventing the spread of COVID-19.

Keywords: temperature, relative humidity, weather, COVID-19, Indonesia

Introduction

The world was stirred by the spread of the Corona virus in Wuhan, China, starting in January 2020, which caused local authorities to impose lockdowns in several affected cities [1–5]. In mid-latitude countries in the northern hemisphere (US, Italy, Spain, Iran, UK, Germany, etc.) the number of patients exposed to the Corona virus Disease 2019 (COVID-19) was increasing. On 11 March 2020, the World Health Organization (WHO) declared COVID-19 as a pandemic due to its global spread [6]. Uniquely, cases in China as the country of origin COVID-19 have declined. The spread of COVID-19 to tropical countries including Indonesia was also becoming increasingly massive. With a total population of nearly 270 million [7], Indonesia is a vulnerable country to such a fast spreading infectious disease.

On March 2, 2020, the Indonesian government announced the first and second cases of COVID-19 infection of two Depok citizens, outside of Jakarta City [8]. The contact tracing showed that transmission to those citizens occurred at an event held on February 14, 2020 in Jakarta. There were foreign citizens attending the event among whom later one person was confirmed infected by the disease. Four days after the first case, another case of COVID-19 was found and afterwards the disease continued to spread. The development of the cumulative rate rapidly followed an exponential pattern. On 15 May, the total of COVID-19 cases reported over all 34 Indonesian Provinces was 16,496 with a total of 1076 mortalities (https://www.worldometers.info/coronavirus/).

The emergence of COVID-19 cases in Indonesia triggered discussions related to the risk of COVID-19 transmission in tropical countries with a warm and humid climate that is very different from the conditions where the disease was first found. Some previous studies revealed that countries located in high altitudes with low temperatures and low humidity have a higher vulnerability compared to tropical countries. They generally found that COVID-19 transmissions were influenced by weather conditions such as temperature [9–15], relative humidity [13,14,16–18] and precipitation [19,20]. Some of these studies indicated that ideal conditions for the corona viruses are temperatures of around 8-10 °C with a relative humidity of about 60-90% [21,22]. Research by Bannister-Tyrrell et al., [9] also found a negative correlation between temperature (above 1 ºC) and the estimated number of COVID-19 cases per day. They showed that COVID-19 had optimum dispersion at very low temperatures (1-9 ºC). This indicates that in countries with high temperatures and high humidity the risk of COVID-19 transmission is actually minimum.

On the other hand, the current situation shows that tropical countries are also vulnerable to COVID-19 exposure. Many tropical countries currently have a high number of COVID-19 confirmed cases (per 15 May 2020) such as Brazil (218,223), India (85,784 cases), Ecuador (31,467 cases), Singapore (26,891 cases) (https://www.worldometers.info/coronavirus/). Additionally, recent publications by Auler et al., [17] and Luo et al., [23] reported COVID-19 cases also thrived in high temperatures , a contradictory conclusion to previous studies [21,24]. This discrepancy in research results suggests that the role of weather factors on COVID-19 transmission is still an open question and topic of debate [24,25].

In Indonesia, the association between weather conditions and COVID-19 cases has been studied by Asyary and Veruswati, [27] and Tosepu et al., [26]. Tosepu et al., [26] found that temperature significantly correlates to COVID-19 cases while Asyary et al [27] reported that

sunlight exposure increased the recovery rate of COVID-19. However, the studies were done over a very short period (one month) and only in one city, i.e. Jakarta. Extending those previous studies in Indonesia, this study aims to comprehensively investigate the role of weather factors in the incidence of COVID-19 in several cities in Indonesia. While the role of social and behavioural factors have been documented considerably (see for example Lakshmi Priyadarsini and Suresh, [28]), literature reporting a robust role of meteorological factors on the COVID-19 transmission, particularly in tropical countries is still scarce.

Data and Methodology

Data

Six cities were selected for this study (See Figure 1-a) considering their cumulative confirmed cases (see Figure 2), their location in the country (north-south of equator line and western-eastern part of the country) to capture variations in climate (see Figure 1-b, 1-c) and the distribution of cases throughout the country. Those six cities are Medan, Jakarta, Bogor, Surabaya, Denpasar, and Makassar. Specifically, Medan is a representative of cities located north of the equator, Bogor is a representative of cities with a relatively high elevation (colder climate) and Denpasar and Makassar are representatives of the eastern part of Indonesia (Table 1).

Daily surface weather data for March-April 2020 were collected from the nearest weather station for each city (see Table 2). We selected four weather variables i.e. average temperature (T-ave), minimum temperature (Tmin), maximum temperature (Tmax) and average relative humidity (RH). Those are variables most frequently investigated in previous COVID-19 studies [19,20,29,30]. T-ave and RH were computed from hourly observations (24 data per day). In addition, we also computed the diurnal temperature range (DTR, Tmax minus Tmin) and absolute humidity (AH). AH was computed following a method used by Luo et al., [23]. Different from RH, AH is a variable describing the actual amount of water vapour in the atmosphere. Previous studies have shown that AH is more correlated to the disease compared to RH [31,32]. To provide climate background of the country, the daily mean temperature and relative humidity from NCEP/NCAR Re-analysis data [33] for March-April during 1981-2010 were used.

Daily data of new cases of COVID-19 were gathered from each local government website (see Table 2). The period of data varies depending on the timing of the first case of COVID-19 found in the respective city, as shown in Table 1. For Makassar city, the COVID-19 data used was the total for South Sulawesi Province since data for Makassar was not available online. However, we assumed that this province level data was still valid for Makassar city considering that the majority of COVID-19 cases in South Sulawesi Province occurred in that city. Only days with non-zero COVID-19 data were included in the analysis.

Method

A descriptive statistical analysis was performed both at city and country level (all data together) to explore the characteristics of confirmed case counts and weather data. Two approaches were then employed to find out the potential association between the incidence of COVID-19 and

weather data i.e. correlation tests and non-linear regression analysis. The correlation test was done for several options of lag time [16,30] to consider the incubation period of COVID-19, which is on average around 5-6 days [34]. This lag time technique is also intended to accommodate the lag effect of medical tests to confirm COVID-19 cases. It is known that COVID-19 reported on a certain day might be due to transmission occurring several days before. In Indonesia, PCR testing (polymerase chain reaction) usually takes several days to complete [35,36] so that confirmed cases are published several days after the time of infection. Our next analysis was based on the best lag time identified from the correlation test (i.e. lag time with the strongest coefficient of correlation). Additionally, to examine associative relationships between weather data and COVID-19 data, the nonlinear regression analysis was employed following a method by Luo et al. [23]. As the last step, we analysed the distribution of COVID-19 data with respect to weather data to point out a possible consistent range of weather data favoured by COVID-19 incidence [37]. This was done by visualizing COVID-19 data on a scatter plot and drawing the contour of 90% data density. This means that the majority of COVID-19 data falls within the contour. By projecting the contour to the weather data (x-axis), we were able to locate the effective range of weather data favouring the COVID-19 incidence.

Results and Discussions

Results

Meteorological Condition

The climatology of temperature and relative humidity during March-April is shown in Figure 1-b and 1-c. Based on NCEP/NCAR Re-analysis data, the March-April temperature in

153 Indonesia ranges from 22-28 ºC while relative humidity ranges from 70-95%. Figure 3 shows the
154 boxplot that represents the descriptive statistics for daily meteorological variable and case numbers
155 of COVID-19 for each city. During March-April 2020, a large variation of the weather conditions
156 was observed in six selected cities in Indonesia. Generally, March and April are months with high
157 monthly rainfall but some parts of eastern Indonesia start to have a dry season onset. Jakarta,
158 Surabaya and Denpasar have the highest T-ave while Bogor has the lowest one among the six
159 cities. For DTR, the lowest (highest) value was found in Jakarta (Bogor). As expected, unlike T-
160 ave, the highest RH was found in Bogor while Jakarta and Surabaya share a nearly similar range
161 of RH data. For AH data, on the other hand, Medan had the highest mean and Bogor had the lowest
162 value. As shown in Figure 3, the range of AH data does not seem connected to other weather data
163 confirming its specific characteristics. In addition, we noted that Denpasar presented a narrow
164 range for T-ave, DTR and RH suggesting small variation of weather there.

165 The COVID-19 data, on the other hand, shows a large discrepancy among cities, with
166 Jakarta having the largest number of confirmed cases. Jakarta as the main international gate to the
167 country is the place where the first case of COVID-19 was found indicating the high risk of Jakarta
168 to this disease. During the study period (Table 1), there were a total of 4138 COVID-19 cases in
169 Jakarta. On average, there were approximately 75 cases of COVID-19 per day in Jakarta, and less
170 than 50 cases per day in other cities. With a population of 11 million, Jakarta is the centre of
171 national transmission of COVID-19 and early cases in other cities were mostly related to events in
172 Jakarta.

Correlation Test

The correlation of the weather variables and COVID-19 data is presented in Figure 4. Except for AH, weather variables show statistically significant correlation for all lag times. Our test found that T-ave is positively correlated with COVID-19 cases even though the coefficient correlation (*r*) is weak with the highest r value of 0.37 found for 1 and 5 days lag time. In contrast, DTR and RH present a significantly negative correlation with relatively similar r values. The strongest correlation for DTR was found for 8 days lag time ($r = -0.39$) and that for RH was found for 5 days lag time ($r = -0.41$). On the other hand, AH shows the weakest correlation to the COVID-19 data, with *r* values ranging from -0.03 to 0.05. Based on the T-ave and RH data, it was observed that the strongest correlation was found for 5 days lag time. This lag time probably indicates the average incubation period of COVID-19 in Indonesia and this is in agreement with the WHO statement about this matter [34]. Another possibility is that this 5 days lag time may represent the average interval between timing of infection and diagnosis by PCR test. However, when looking at each city (Table 3, Supplementary Material), the *r* value and the lag time having the strongest correlation vary among cities.

Regression Analysis

The results of a nonlinear regression analysis between weather variables and COVID-19 data on 5 days lag time are visualized in Figure 5. In general, the coefficient of determination (R^2) for all variables is less than 20%, indicating that only a small part of variance of COVID-19 data can be explained by weather variability. However, considering the statistically significant correlation between those two data, it is worth discussing the characteristics of COVID-19 data with respect to the range of weather data in this study.

As shown in Figure 5, the plot suggests that the confirmed number of cases increased with an increase of temperature, in the range of 25-31°C. In contrast, in the range of 3-11°C (65-95%), the confirmed cases declined as the DTR (RH) increased. On the other hand, the AH presents a different pattern of relationships with more confirmed cases found at the AH of around 18-20 g/m3, the middle part of all distributions.

Distribution Analysis

To get an idea of the effective range of weather data favouring COVID-19 transmission in Indonesia, we analysed the distribution of COVID-19 data with respect to T-ave, DTR, RH, and AH, as shown in Figure 6. During March-April 2020, 90% of confirmed cases in the six selected cities (shown by contour on the scatter plot) occurred in the range of T-ave approximately between 25-31°C. Additionally, the bounds of DTR of 90% of total confirmed cases was around 4-11 ^{o}C, and that of RH (AH) was about 74-92% (17-21 g/m3). Outside of those bounds, the number of confirmed cases were generally low. For instance, for T-ave > 31 or RH < 74%, the number of confirmed cases was minimum. These results may indicate the particular range of weather conditions that favour COVID-19 incidence.

Discussion

This is the first time that the link between meteorological factors and COVID-19 incidence in multi-cities in Indonesia has been investigated comprehensively. Our study extends the research by Tosepu et al [26] which examines the correlation between weather and COVID-19 pandemic in Jakarta, Indonesia. Our work also contributes to the insight into the characteristics of COVID-19 cases particularly in tropical climates which are still limited in the literature [17]. It is known

216 that most of the research on the link of weather data and COVID-19 cases available in the literature
217 comes from sub-tropical countries [29,38,39].

218 We found that during the study period, the daily average temperature positively correlated
219 to the COVID-19 cases, in agreement with previous studies reported by Auler et al., [17], Liu et
220 al., [30] and Tosepu et al., [26]. In contrast, DTR and RH present a significant negative correlation
221 with COVID-19 data while AH shows an inconsistent correlation among all lag times studied. Our
222 findings on the role of T-ave and DTR are consistent with the study by Liu et al [30] who found
223 that the number of confirmed cases in China during the period of January 20th to March 2nd, 2020
224 tended to increase (decline) following an increase in temperature (DTR). It was also found in our
225 study that a lag time of 5 days presented the strongest correlation for T-ave and RH which probably
226 indicates the average time between exposure and diagnosis.

227 The link between weather data and the COVID-19 data was also confirmed by the results
228 of regression analysis with a 5-day lag time. As shown in Figure 5, we observed that the number
229 of confirmed cases increased following an increase in temperature, or the decrease of DTR and
230 RH. These findings indicate that the COVID-19 incidence may be partially affected by
231 meteorological factors. However, it is important to mention that both the coefficient correlation
232 and coefficient of determination was considerably low i.e. about -0.4 to 0.4 and less than 20%,
233 respectively. This low value suggests that the effect of meteorological factors is limited and the
234 COVID-19 incidence might be largely influenced by non-meteorological factors. It seems that the
235 significant positive correlation between T-ave and COVID-19 data was found because the
236 temperature gradually increased from March to April following the seasonal change while at the
237 same time, the confirmed cases of COVID-19 increased due to the rapid spread of this disease.

238 Our findings are somewhat in contrast with previous studies conducted in regions with
239 colder climates which reported that the increase in temperature could reduce COVID-19
240 transmission [11,18]. They, in general, found that lower temperatures favoured COVID-19 cases.
241 However, later studies in China by Liu et al., [30] and in Brazil by Auler et al., [17] reveal that the
242 increase of temperature is followed by an increase of confirmed cases and high temperature
243 supports COVID-19 transmission as well. This contradictory finding indicates that the potency of
244 high temperature and high humidity in reducing the transmission of COVID-19 might not be valid
245 for tropical regions where the average temperature and relative humidity is climatologically high.
246 For instance, the six selected cities in Indonesia during the months March and April 2020 registered
247 a daily temperature of higher than 25 °C and a daily relative humidity of more than 65%. This
248 range of weather data is beyond the effective bound for COVID-19 cases suggested by previous
249 studies [21,22]. Furthermore, our distribution analysis revealed that the majority of COVID-19
250 cases (90% of cases) occurred within the temperature range of 25-31ºC and RH range of 74-92%.
251 Our results are in agreement with the study by Auler et al., [17] who found that the COVID-19
252 transmission rate in Brazil was initially observed to be favoured by higher mean temperatures (27.5
253 °C) as well as intermediate relative humidity (near 80%).

254 We emphasize that this study presenting a preliminary analysis and the investigation was
255 limited to meteorological factors. A longer study period and more sampling of affected cities might
256 better represent the association between meteorological conditions and COVID-19 incidence. It
257 has been reported that, besides being influenced by meteorological factors, the number of
258 confirmed COVID-19 cases in a country depends on multiple factors including the extent of testing
259 conducted [40], population [19,29], social dynamics/migration scale [10,41,42], governmental
260 policies such as the limitation of public transport [38,43,44] etc. In Indonesia, the number of daily

confirmed cases at national level is closely correlated with the extent of testing conducted with a coefficient correlation of 0.71 suggesting that the detected confirmed cases depend largely on the extent of testing conducted by the government (Figure 7).

Conclusions

Our study demonstrates that weather conditions are weakly associated with the COVID-19 incidence particularly in the six selected cities in Indonesia. This is the first comprehensive research that has attempted to explore the effects of meteorological factors on the COVID-19 cases in multi-locations in Indonesia, an example of a country with a tropical climate. Daily mean temperature (diurnal range of temperature and relative humidity) present statistically positive (negative) significant correlation to confirmed COVID-19 cases. During the selected study period, March-April 2020, the majority of COVID-19 incidence in Indonesia was observed to occur in the daily temperature range of 25-31°C and relative humidity of 74-92%. However, it should be noted that the effect of meteorological factors is limited, considering the low value of coefficient correlation and coefficient of determination presented in this study. Thus, non-meteorological factors have to be considered to have more control over the COVID-19 pandemic.

Declaration

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Conflicts of interest/Competing interests

The authors declare that they have no known competing interests or personal relationships that could have appeared to influence the work reported in this paper.

Availability of data and material (data transparency)

Not applicable

Code availability (software application or custom code)

Not applicable

Authors' contributions

Supari and D.E. Nuryanto contributed equally as the main contributor of this paper. All authors were involved in reviewing and editing the original manuscript.

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List of Tables

Table 1. List of selected cities and their characteristics

CITY	ELEVATION	NORTH-SOUTH	WEST-EAST	PERIOD OF DATA
MEDAN	< 50 m	North	West	28 March 2020 – 30 April 2020
JAKARTA	< 10 m	South	West	2 March 2020 – 30 April 2020
BOGOR	> 250 m	South	West	21 March 2020 – 30 April 2020
SURABAYA	< 10 m	South	West	23 March 2020 – 30 April 2020
DENPASAR	< 100 m	South	East	1 April 2020 – 30 April 2020
MAKASSAR	< 25 m	South	East	15 March 2020 – 30 April 2020

Table 2. Source of weather and COVID-19 data for six selected cities

CITY	SOURCE OF WEATHER DATA	SOURCE OF COVID-19 DATA
MEDAN	Kualanamu Airport Weather Station	https://covid19.pemkomedan.go.id/
JAKARTA	Kemayoran Weather Station	https://corona.jakarta.go.id/id
BOGOR	Dramaga Climate Station	https://pikobar.jabarprov.go.id/
SURABAYA	Djuanda Airport Weather Station	https://lawanCOVID-19.surabaya.go.id/
DENPASAR	Ngurah Rai Airport Weather Station	https://safecity.denpasarkota.go.id/id/covid19
MAKASSAR	Hasanudin Airport Weather Station	https://covid19.sulselprov.go.id/

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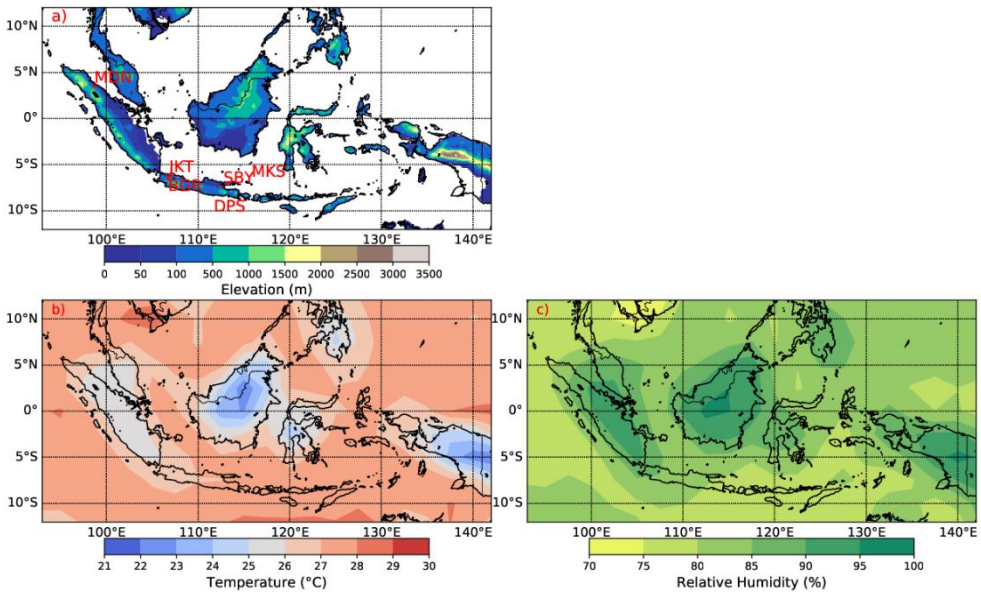

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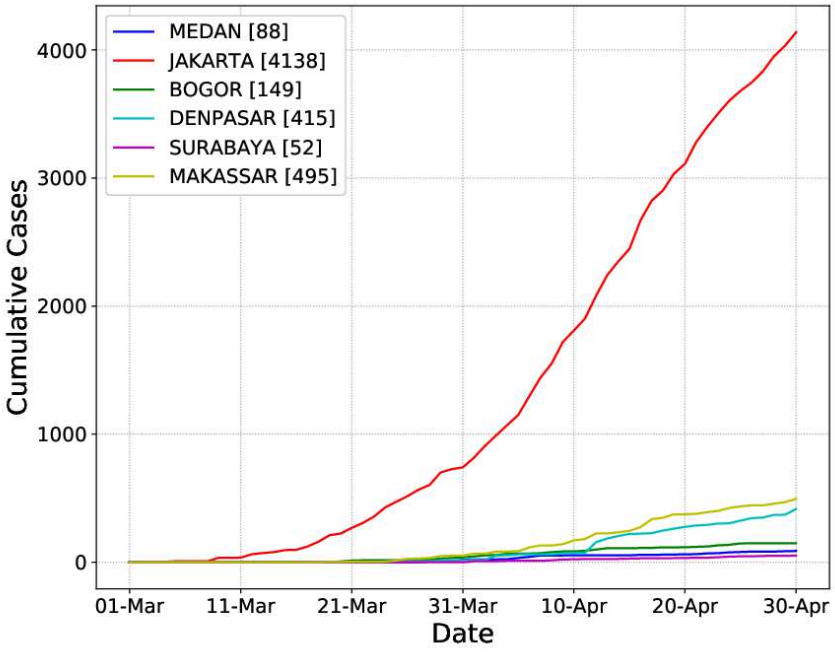


Figure 2

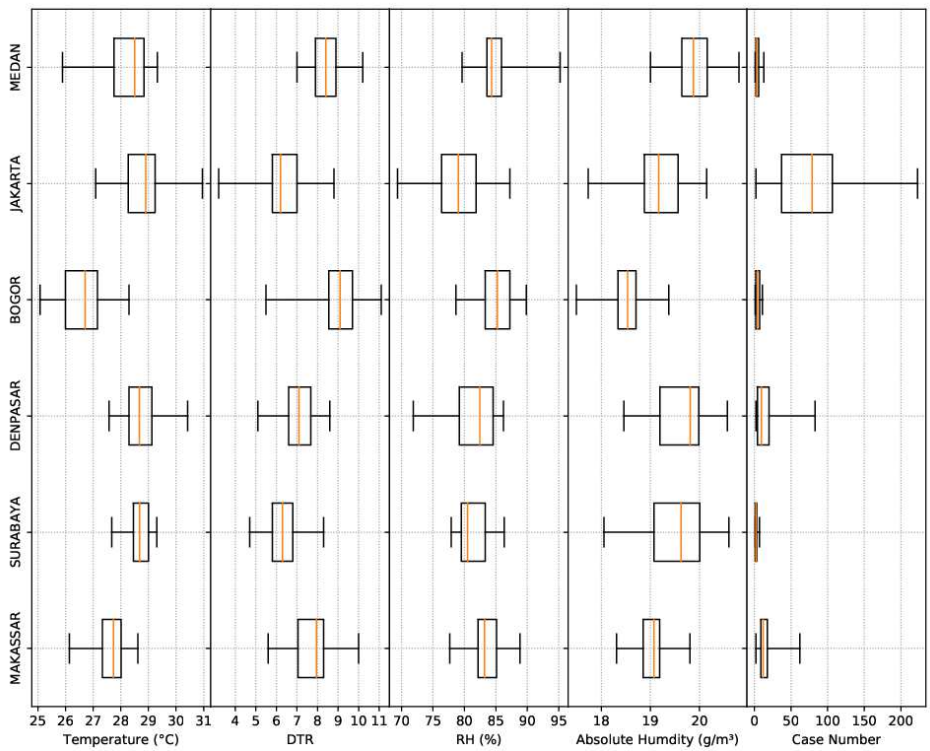
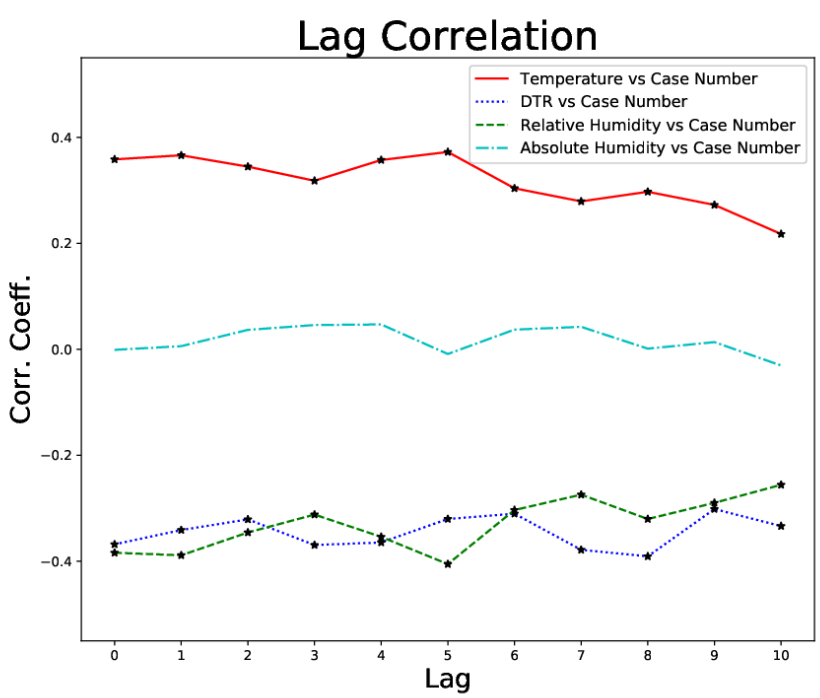


Figure 3



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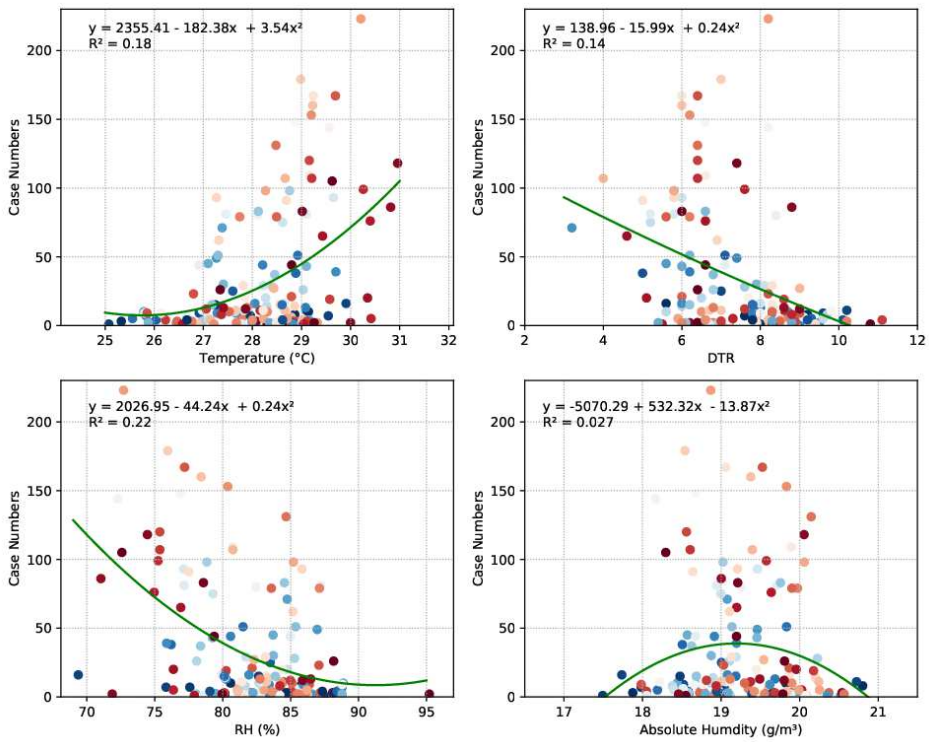

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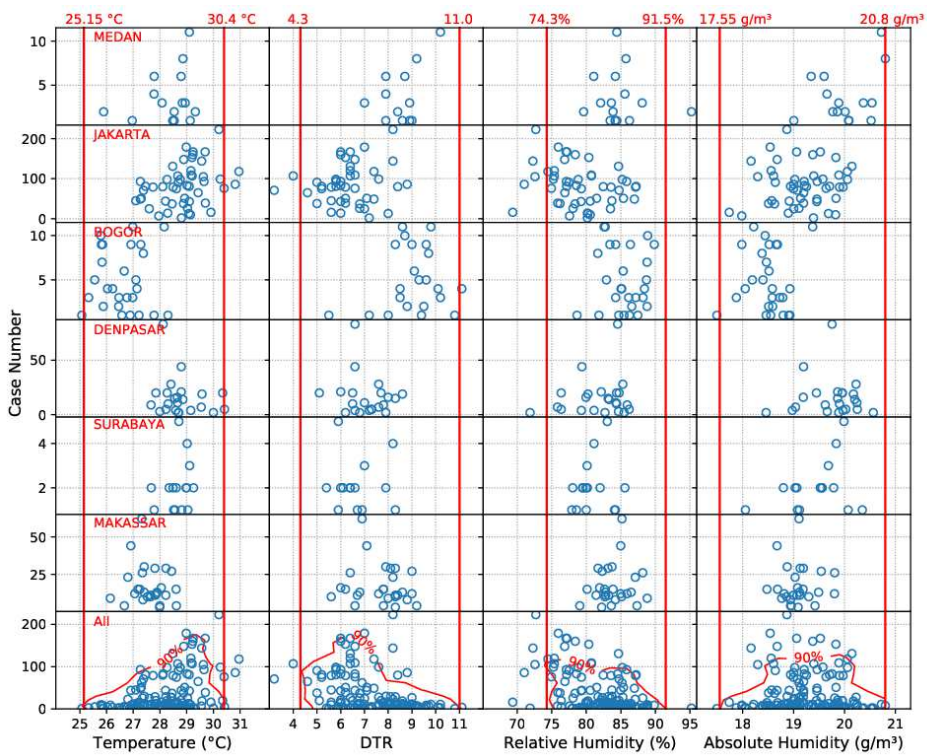


Figure 6

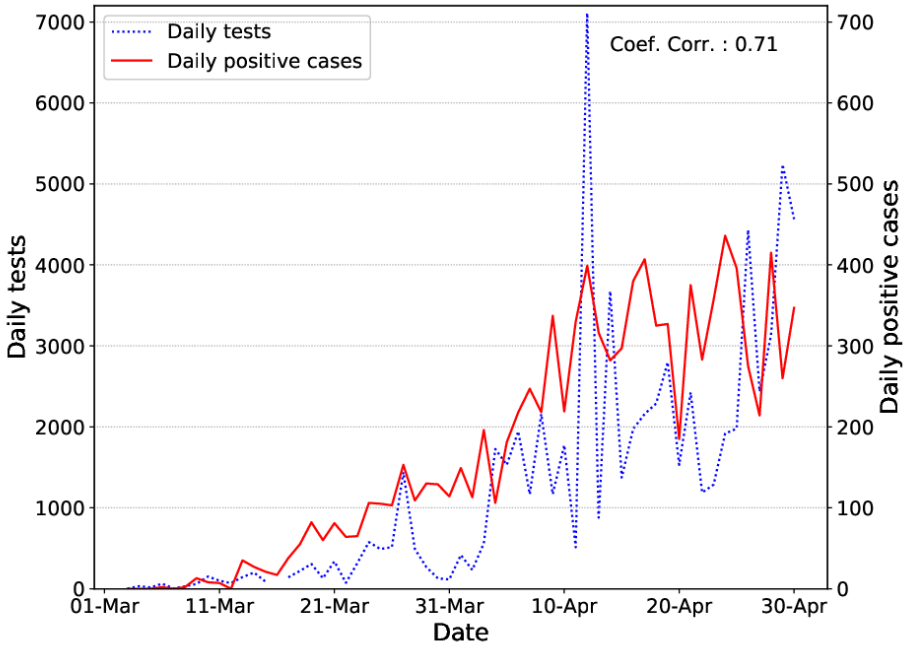

Daily tests
Daily positive cases
Coef. Corr. : 0.71
Daily tests
Daily positive cases
Date
0
1000
2000
3000
4000
5000
6000
7000
0
100
200
300
400
500
600
700
01-Mar
11-Mar
21-Mar
31-Mar
10-Apr
20-Apr
30-Apr

Figure 7

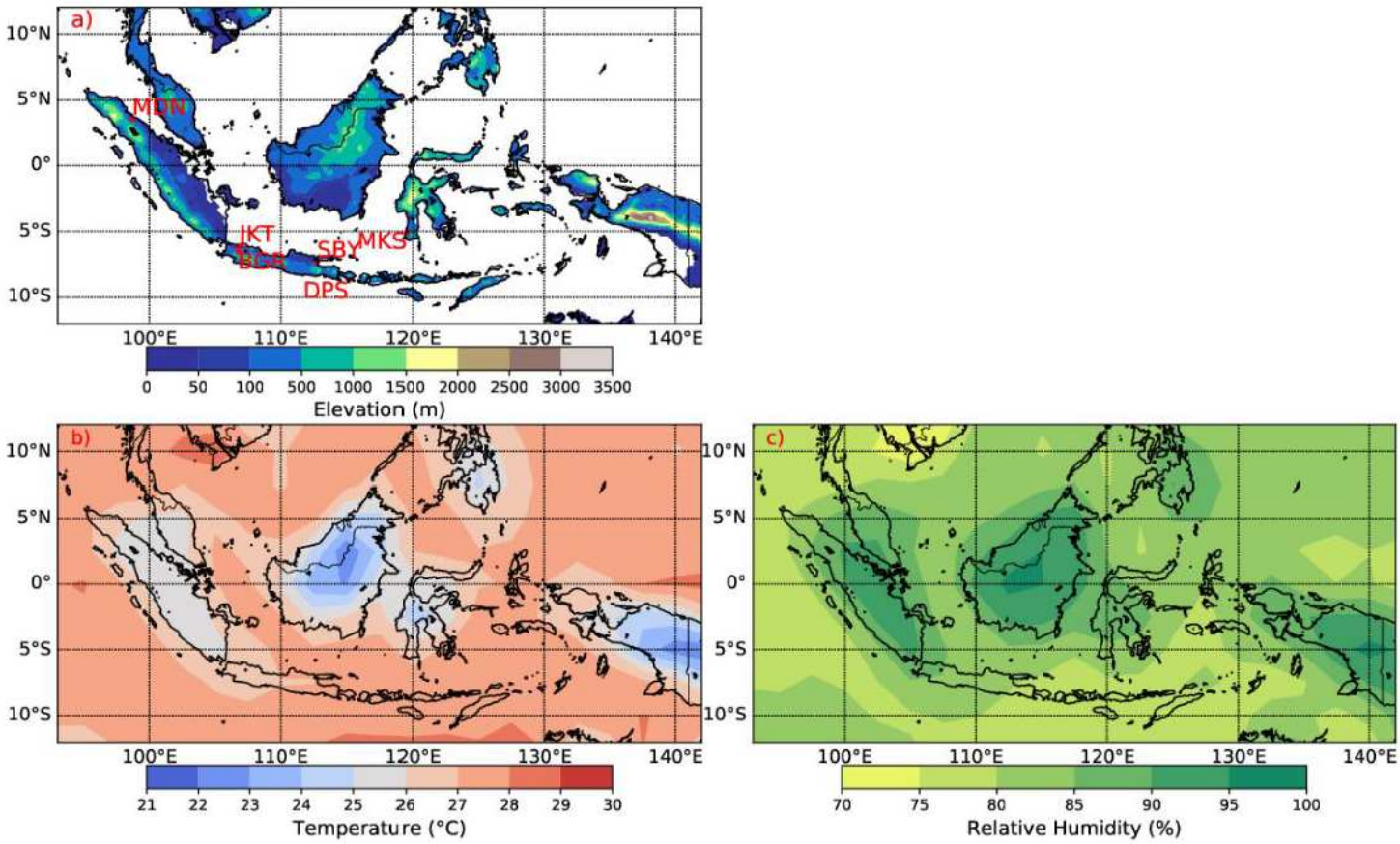
Supplementary Material

Table 3. Summary of lag correlation between meteorological parameters versus new cases of COVID-19 for each city. The asterisk symbol denotes statistically significant correlation.

Parameters	Lag	MEDAN	JAKARTA	BOGOR	DENPASAR	SURABAYA	MAKASSAR
Temperature	0	0.15	0.24	0.32	-0.14	0.32	-0.052
	1	-0.27	0.26	0.21	-0.099	0.29	0.095
	2	0.16	0.19	0.056	-0.18	0.29	0.064
	3	-0.037	-0.0012	0.27	0.13	-0.019	0.26
	4	0.5*	0.2	-0.079	-0.062	-0.19	-0.2
	5	0.25	0.33*	0.029	-0.2	0.25	-0.12
	6	0.34	0.032	-0.4*	0.19	-0.048	0.2
	7	0.28	-0.016	-0.17	-0.13	0.064	0.14
	8	-0.47	0.19	0.059	0.45*	-0.3	-0.41*
	9	0.088	0.16	0.016	0.049	-0.72*	-0.062
	10	-0.89*	0.056	-0.14	0.051	0.017	-0.086
DTR	0	0.56*	-0.088	0.17	0.078	0.025	-0.024
	1	0.08	0.037	0.053	0.14	-0.057	-0.11
	2	-0.1	0.11	-0.49*	-0.039	0.056	0.052
	3	0.088	-0.1	0.21	-0.051	-0.093	0.075
	4	0.46	-0.04	-0.11	0.26	-0.18	-0.29
	5	0.48	0.13	0.16	-0.16	-0.0063	-0.16
	6	0.2	0.12	0.35	-0.29	0.46	0.18
	7	-0.02	-0.13	0.055	-0.11	0.33	0.014
	8	-0.35	-0.093	-0.3	0.022	0.19	-0.19
	9	-0.55	0.095	-0.043	0.38	0.18	0.058
	10	-0.57	-0.038	-0.28	-0.24	-0.21	0.14
Relative Humidity	0	-0.003	-0.11	0.32	-0.068	-0.45*	0.081
	1	0.28	-0.12	0.21	0.023	-0.19	-0.067
	2	0.045	-0.025	0.056	0.003	-0.17	0.029
	3	0.062	0.15	0.27	-0.17	-0.056	-0.21
	4	-0.089	-0.044	-0.079	0.13	0.19	0.16
	5	-0.088	-0.24	0.029	0.16	0.15	0.14

	6	-0.095	0.084	-0.4*	-0.22	0.39	-0.13
	7	-0.47	0.15	-0.17	0.12	0.38	-0.13
	8	0.2	-0.054	0.059	-0.66*	0.1	0.36
	9	-0.25	-0.036	0.016	-0.064	-0.32	-0.041
	10	0.37	-0.0019	-0.14	-0.065	-0.26	0.0086
Absolute Humidity	0	0.29	0.17	0.32	-0.3	-0.21	0.059
	1	-0.034	0.19	0.21	-0.097	0.023	0.04
	2	0.38	0.25	0.056	-0.23	0.05	0.16
	3	0.049	0.27	0.27	-0.14	-0.07	0.12
	4	0.75*	0.23	-0.079	0.15	0.019	-0.091
	5	0.34	0.075	0.029	-0.00097	0.34	0.0094
	6	0.33	0.2	-0.4*	-0.13	0.34	0.17
	7	-0.046	0.24	-0.17	-0.018	0.4	0.074
	8	-0.44	0.19	0.059	-0.48*	-0.098	-0.3
	9	-0.1	0.18	0.016	-0.046	-0.61*	-0.24
	10	-0.81*	0.068	-0.14	-0.046	-0.19	-0.2

Figures



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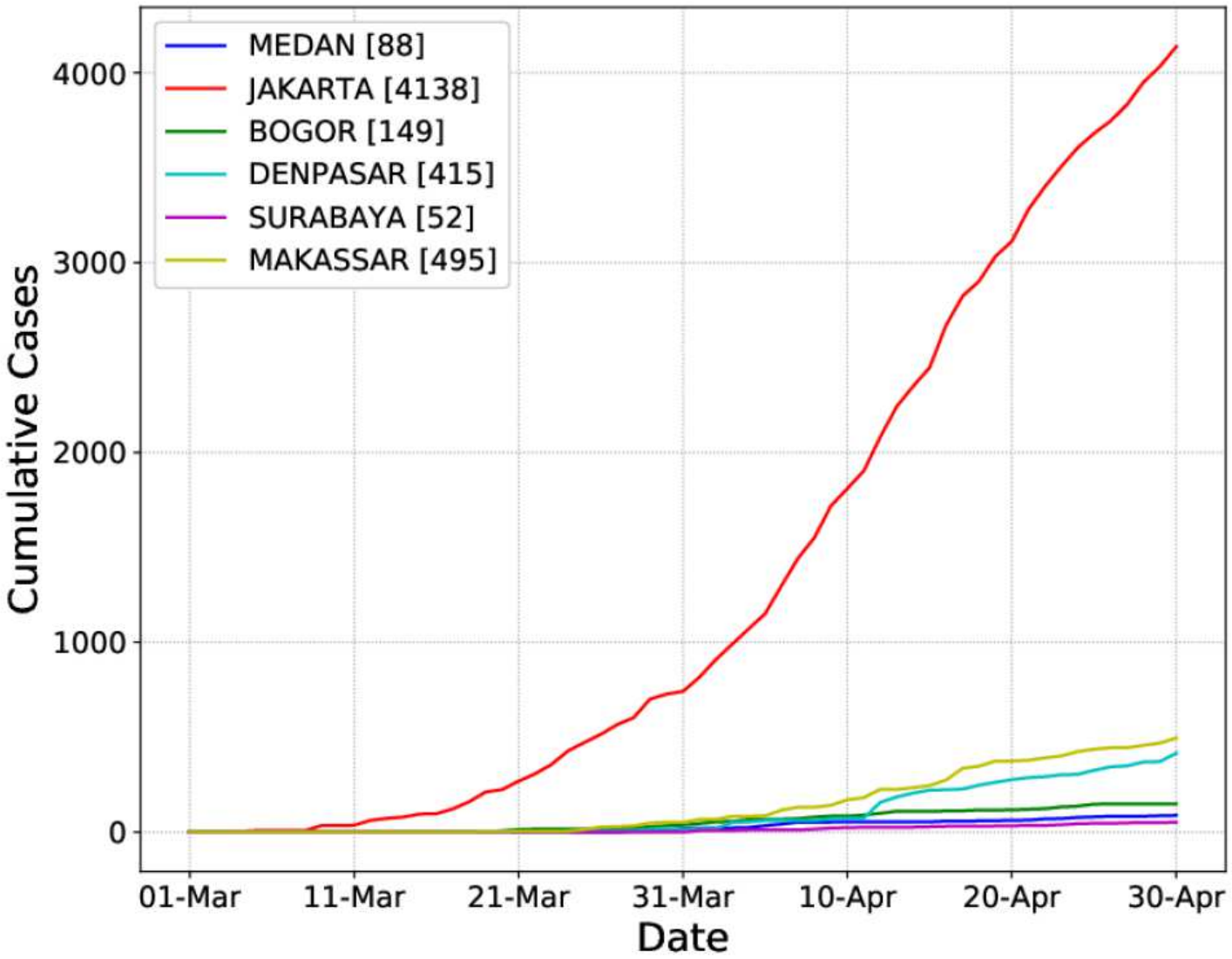
The map showing the location of six selected Indonesian cities and its elevation (a), the climatology of daily temperature (b) and relative humidity (c) for March-April based on NCEP/NCAR Re-analysis data. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.



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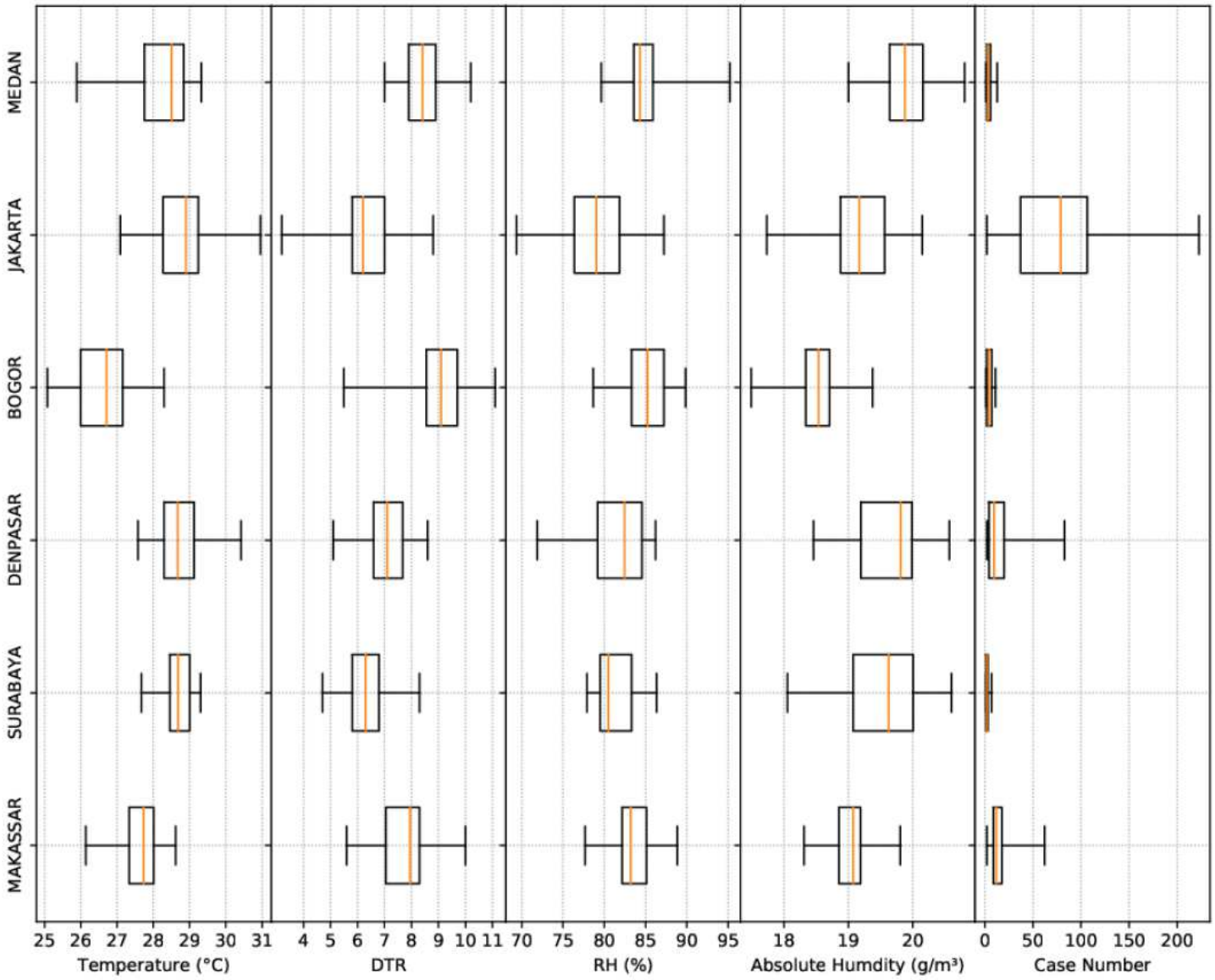

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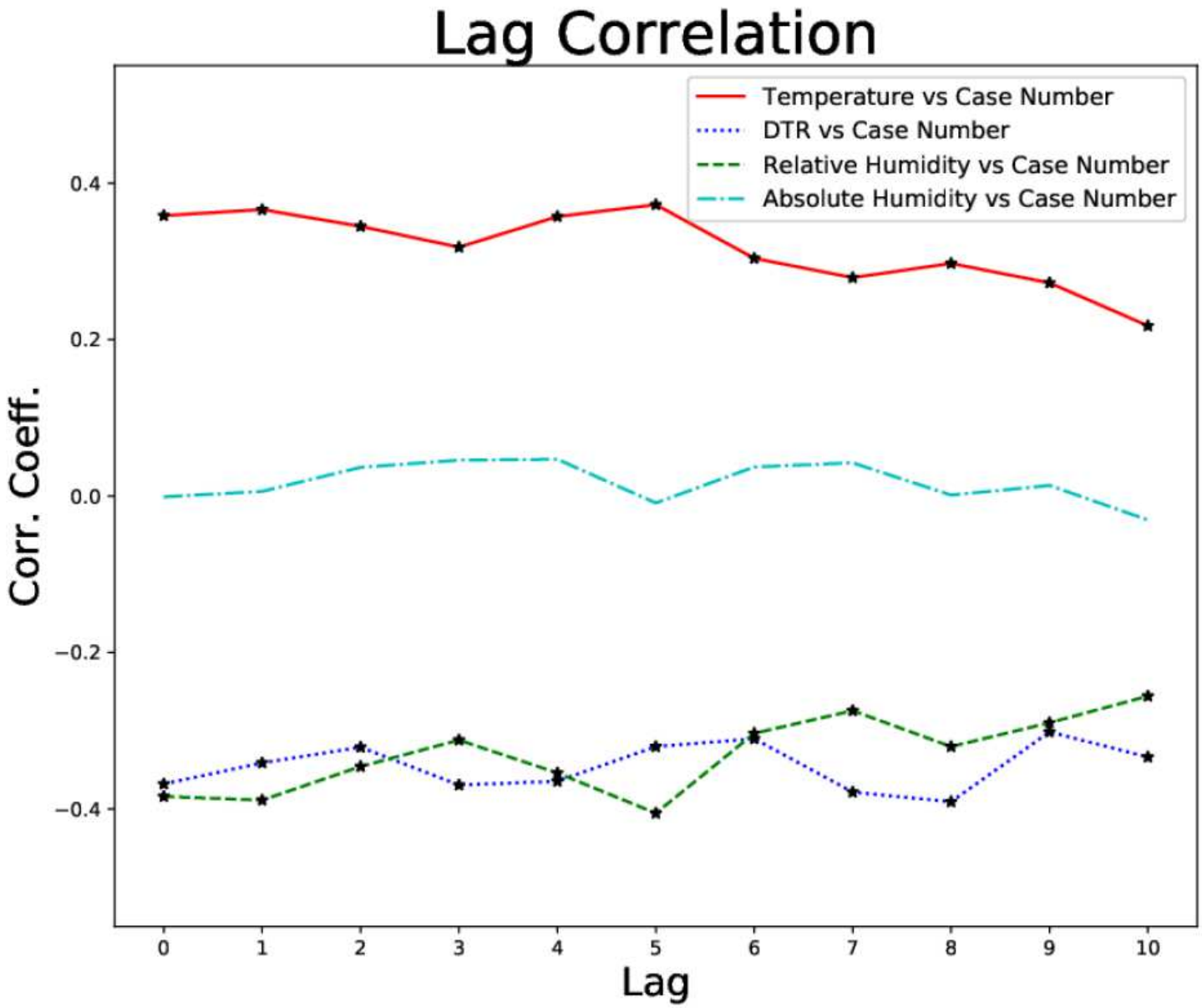

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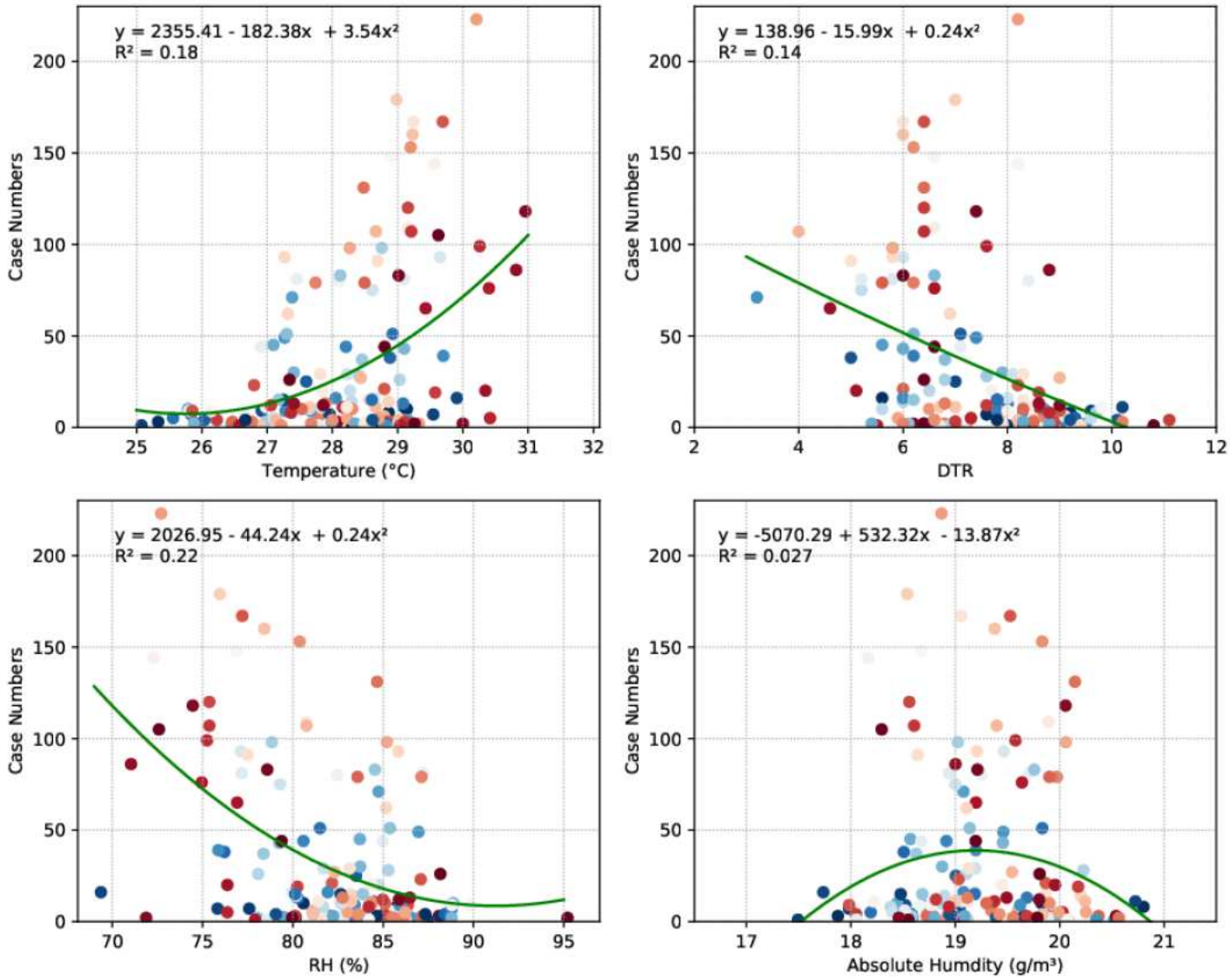

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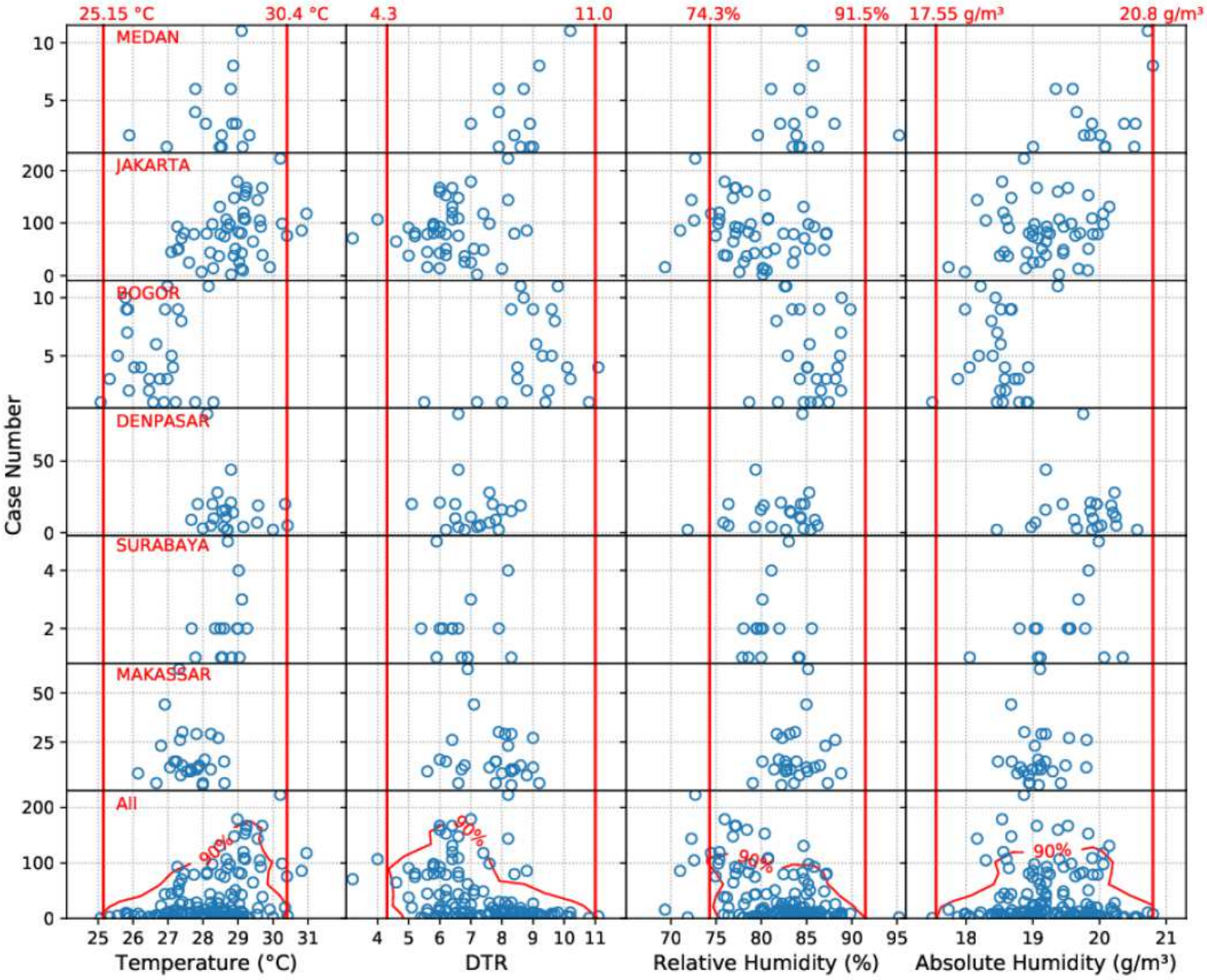

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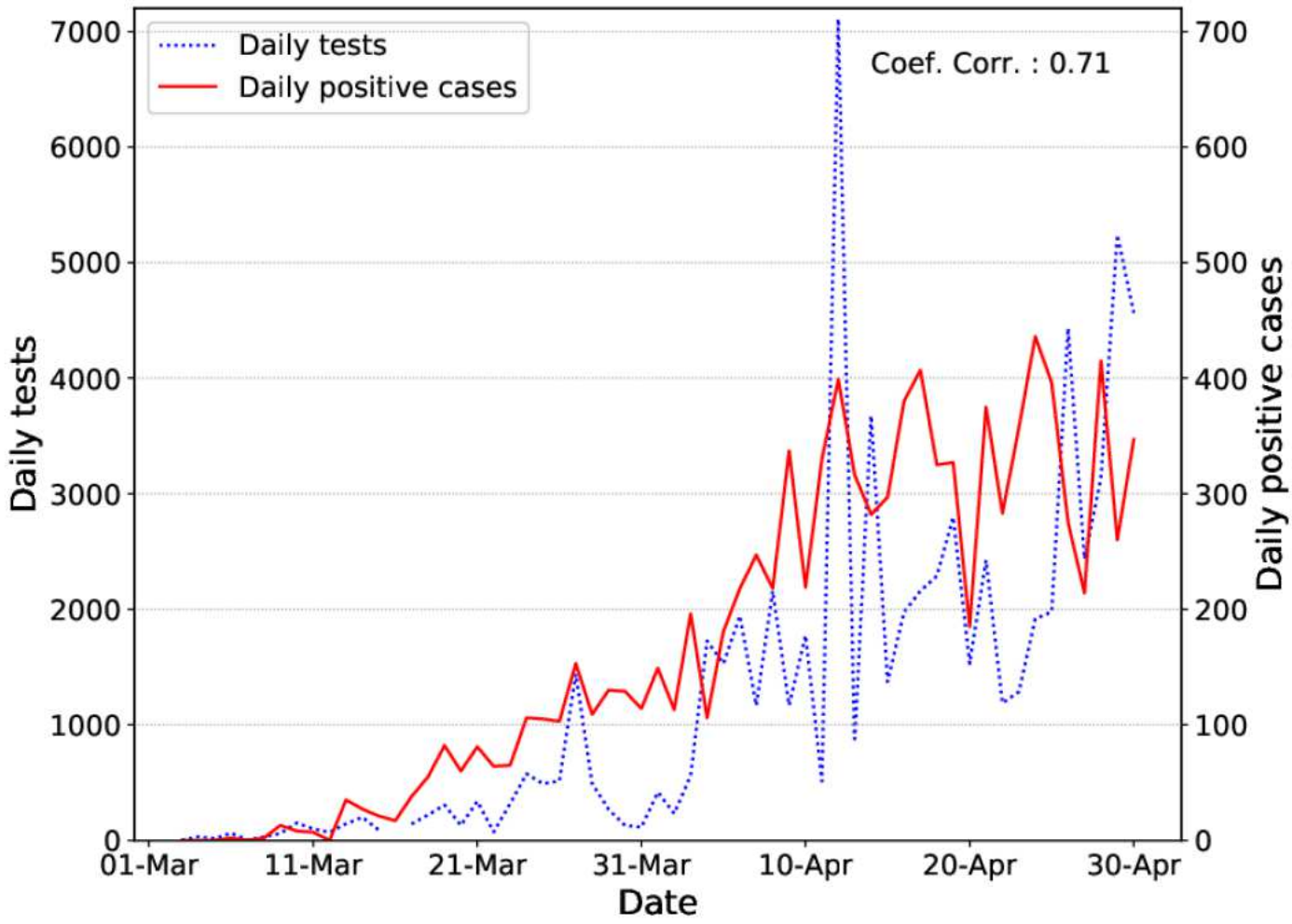

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