

Meteorological factors correlate with transmission of 2019-nCoV: Proof of incidence of novel coronavirus pneumonia in Hubei Province, China

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Abstract:

Objective: many potential factors contribute to the outbreak of COVID-19. The aim of this study was to explore the effects of various meteorological factors on the incidence of COVID-19.

Methods:

Taking Hubei province of China as an example, where COVID-19 was first reported and there were the most cases, we collected 53 days of cases up to March 10(total 67773 confirmed cases).COVID-19 confirmed cases were retrieved from the official website of Hubei Health Commission. Ten meteorological parameters were provided by China meteorological administration, including average pressure (hPa), average temperature (°C), maximum temperature, minimum temperature (°C), average water vapor pressure (hPa), average relative humidity (%),etc. Cross correlation analysis and linear regression were used to judge the relationship of

meteorological factors and increment of COVID-19 confirmed cases.

Results:

Under 95% CI, the increment of confirmed cases in Hubei were significantly correlated with four meteorological parameters of average pressure, average temperature, minimum temperature and average water vapor pressure (equivalent to absolute humidity). The average pressure was positively correlated with the increment ($r=+0.358, p=0.010$). The negative correlations included average temperature ($r=-0.306, p=0.029$), minimum air temperature ($r=-0.347, p=0.013$), average water vapor pressure ($r=-0.326, p=0.020$). The linear regression results show if minimum temperature increases by 1℃, the incremental confirmed cases in Hubei decreases by 72.470 units on average.

Conclusion:

The incidence of COVID-19 was significantly correlated with average pressure, average temperature, minimum temperature and average water vapor pressure. It is positively correlated with the average pressure and negatively correlated with the other three parameters. Compared with relative humidity, 2019-nCoV is more sensitive to water vapor pressure. The reason why the epidemic situation in Hubei expanded rapidly is significantly related to the climate characteristics of low temperature and dryness of Hubei in winter.

Keywords: 2019-nCoV, COVID-19, meteorological factors, pandemic, meteorological disasters, average water vapor pressure, average minimum temperature, average atmospheric pressure

1 Introduction

On December 2019, 27 cases of unknown pneumonia broke out in Wuhan, Hubei province (Wuhan City Health Committee, 2019). On January 9, 2020, the China Center for Disease Control and Prevention (CCDC) reported to the world that a new coronavirus (2019-nCoV) was detected in these serious cases (Corman, et al., 2020). On January 22, 2020, Hubei Health Commission announced the outbreak of new coronavirus pneumonia (COVID-2019) to the public and shared all data on disease transmission (Holmes, 2020). CCDC's announcement on detection of the 2019-nCoV coronavirus led the World Health Organization (WHO) to declare an emergency (Chan,

2020a;2020b). On March 10, 2020, a total of 67773 cases have been confirmed in Hubei province. On March 11, the new coronavirus disease (COVID-19) spread to 114 countries and the confirmed cases around the world were close to 120,000, WHO made the assessment that COVID-19 can be characterized as a pandemic (WHO, 2020).

A large number of studies, including epidemiological studies and laboratory analysis have shown that meteorological factors play an important role in the survival and transmission of viruses (Braga et al., 2001; Liu et al., 2014; Zanobetti et al., 2002; Fraser et al., 2004; Brito et al., 2019; Sagripanti & Lytle,2007).

Epidemiological studies have found that viral respiratory infectious diseases have exact correlation with meteorological factors. The study on severe acute respiratory syndrome (SARS) points out that there is a significant correlation between temperature and virus transmission, and three key factors, namely temperature, humidity and wind speed, promote the transmission of SARS (Yuan et al., 2006; Chan et al.,2011; Tan et al., 2005). Some studies have revealed that when the climate conditions are relatively cold and dry, Middle East respiratory syndrome (MERS) is more likely to occur -(Gardner et al., 2019), while high temperature and high humidity significantly reduce the spread of influenza (Lowen et al., 2008; Shaman & Kohn,2009; Steel et al.,2011; Park et al.,2020). Studies on respiratory syncytial virus (RSV) show that RSV is prevalent throughout the year in temperate climate areas. Atmospheric conditions, especially temperature, to a certain extent explain the annual changes of RSV activity (Noyola et al., 2008), and the strongest RSV activity is in winter, a lower temperature. In areas with lower temperatures throughout the year, RSV continues to maintain activity (Yusuf et al.,2007); there are also studies showing that, relative humidity(RH), minimum temperature and cloud amount are important predictors of RSV activity (Meerhoff et al., 2009). Studies on the relationship between atmospheric pressure and virus transmission show that, average temperature and atmospheric pressure are the most important variables related to RSV activity, and other factors such as water vapor pressure, RH and minimum temperature also seem to play a role. Among them, the RSV activity increased with the increase of atmospheric pressure (Hervès et al., 2012).

Laboratory research further verified the sensitivity of the virus to meteorological parameters (including aerosol), and the experiments covered influenza virus (Lipsitch & Viboud, 2009; Steel

et al., 2011; Shaman et al. & Kohn, 2009; Dalziel et al., 2018), swine flu virus (Lowen et al., 2007), SARS-Cov (Chan et al., 2011), MERS-CoV (van Doremalen et al., 2013), coronavirus (Casanova et al., 2010; Kim et al., 2007). The effects of different meteorological parameters (temperature, RH, absolute humidity, atmospheric pressure) and other meteorological factors on viral transmission or viral activity, were studied and some relevant mechanisms were revealed. However, it still cannot be fully explained. For example, studies have suggested that the survival of influenza virus is affected by the amount of water vapor pressure (equal to absolute humidity, AH) in the surrounding air, however, it is unclear why the stability of an influenza virus encased within a droplet nucleus would be sensitive to atmospheric water vapor pressure conditions. It is presumed that high atmospheric humidity levels will lead to surface inactivation of lipid-containing viruses, such as influenza viruses (Shaman et al. & Kohn, 2009).

A variety of statistical methods were used for mathematical modeling to further reveal the potential laws. Kim et al. believed that the incidence and mortality of diseases followed the Poisson distribution and used Poisson function as the link function to establish a generalized linear model (GLM) (Kim et al., 2016). Lim et al. used the cross design of Poisson GLM and temperature-matched case. Through case cross design, personal characteristics and long-term and seasonal trends can be controlled (Lim et al., 2012). GLM was also used in the studies of Onozuka et al. and Souza et al. (Souza et al., 2012; Onozuka et al., 2009). For seasonal viral infectious diseases, Gurgel et al. and Yusuf et al. used time series analysis to reduce model deviations (Gurgel et al., 2016; Yusuf et al., 2007). Chan et al., du Prel et al., Lin et al., Varela et al. use the autoregressive integral moving average (ARIMA) model to control the autocorrelation of time series data (Chan et al., 2002; du Prel et al., 2009; Lin et al., 2009; Varela et al., 2004). Carreras et al. used a generalized additive model (GAM) using a quasi-Poisson distribution as link function. In this study, the daily temperature range (DTR) was used as the main predictor, and other control variables included day of the week, RH and PM10. These variables are included in the model as linear terms. In the secondary analysis, the same model was used, but all variables were stratified by season, age group, seasonal pattern and socioeconomic status (Carreras et al., 2015). In China, another study used GAM and controlled long-term trends. In addition, the average temperature was fitted into the model to explore the logarithmic risk of daily hospitalization (Bai YL, et

al.2019).

However, whether this relationship exists in respiratory infections caused by viruses other than influenza is unclear, furthermore, laboratory studies of novel coronavirus (2019-ncov) related to meteorological factors have not been reported.

So far, the research on the COVID-2019 and the climatic characteristics of Hubei province in China has not been reported. Similarly, the relationship of the COVID-19 epidemic and meteorological factors has been unavailable in published professional journals. The purpose of this study is to unfold whether the meteorological factors have influence on the 2019-nCoV transmission and the occurrence and development of epidemic diseases, and to explore in detail the relationship between the explosion of confirmed cases and meteorological factors under subtropical monsoon climate conditions, this is of practical significance for predicting the extinction of the virus. Due to the different characteristics of virus transmission in different latitude regions, therefore, with appropriate spatial resolution, Hubei province is used instead of China or Wuhan City (i.e., at provincial level rather than national level, also not city level) analyzing surveillance data is very important for understanding the global persistence of viruses and formulating local prevention and control measures.

This study designed the correlation analysis between the COVID-19 increment cases in Hubei province and 10 meteorological parameters and the regression analysis of four sensitive parameters, combined with the meteorological characteristics of Hubei province, namely cold and dry in winter, hot and rainy in summer with frequent meteorological disasters, in order to find the relevant clues of meteorological factors on the occurrence, development and extinction of COVID-19.

2 Methods

Ethics statement

COVID-19 surveillance data used in this study was gathered from the website of Health Commission of Hubei Province. Data were collected based on the guideline for <Diagnosis and Treatment of Pneumonitis Infected with New Coronavirus (Trial Fifth Edition)> issued by the General Office of National Health Commission and Office of the State Administration of Traditional Chinese Medicine. Surveillance data were aggregated monthly and were analysed

anonymously. The Meteorological Data Center of the China Meteorological Administration provided Hubei Meteorological Observatory data from December 1, 2019 to March 10, 2020 (100 daily weather observation). Therefore, ethical approval was not required.

2.1 Study population

(1) Meteorological Observatory data

According to the suggestion of the Meteorological Data Center of China Meteorological Administration, the coordinates of the representative weather stations in Hubei are as follows (Latitude: 30 degrees 35 minutes 52 seconds, Longitude: 114 degrees 03 minutes 02 seconds, altitude: 23.6 (the altitude is calculated from Qingdao tide inspection station in Shandong as the starting point)). The available data period is from December 1, 2019 to March 10, 2020 (100 daily meteorological data). The actual data selected starts on January 1, 2020 and ends on March 10, 2020. Meteorological observatory data include: average air pressure (hPa), average temperature (°C), maximum temperature (°C), minimum temperature (°C), average water vapor pressure (hPa) (equivalent to water vapor pressure), average relative humidity (%), average wind speed (m/s), precipitation (mm), total solar radiation (0.01 megajoules/square meter), maximum solar irradiance (Watt/square meter). Afterwards, it uses Ave_Pre, Ave_Temp, Max_Temp, Min_Temp, Ave_WVP, Ave_RH, Ave_WS, Prep, Tot_SR and Max_SI to refer to them respectively.

According to the suggestion of the Meteorological Data Center of China Meteorological Administration, the average water vapor pressure (hPa) should be introduced as a quantity representing the moisture content in the atmosphere. When there is much water vapor in the atmosphere, the water vapor pressure is large and vice versa.

(2) Number of confirmed cases

Wuhan Health Committee reported that the local epidemic situation in Wuhan was reported on December 27. After tracing to the source, it was confirmed that the first patient was diagnosed in December 12. For a long time, Wuhan Health Committee had been using "unexplained viral pneumonia" rather than COVID-2019 before this, so the cases could not guarantee its authenticity.

After January 16th, 2020, especially on 17th and 18th, the state has delegated the power of virus testing to the Hubei Center for Disease Control (HCDC), that is, the samples do not need to be sent to Beijing, and can be tested in the local organization, HCDC detection capability is about

300 cases per day. Due to the improvement of detection ability and speed, the number of confirmed cases on the 17th and 18th increased. This study uses January 17, 2020 as the starting point of time to retrieve data. Case data include Hubei's cumulative confirmed cases (67773 as of March 10), Hubei's cumulative death (3046 as of March 10), and Hubei's incremental cases, namely HB_CumN, HB_CumD, and HB_DeltaN respectively.

As for number of confirmed cases, several issues to be explained:

1) From 0: 00 to 24: 00 on February 12, 2020, the number of newly incremental cases of COVID-19 in Hubei province surged explosively to 14840 (including 13332 clinically diagnosed cases), in which are 13436 cases in Wuhan. The reason was that the General Office of the State Health Commission and the Office of the State Administration of Traditional Chinese Medicine issued the new coronavirus infection pneumonia diagnosis and treatment plan (trial version 5). Type of "Clinical Diagnosis" has been added to the classification of case diagnosis in Hubei province, so that patients can receive standardized treatment as early as possible according to confirmed cases and further improve the success rate of treatment. According to this plan, Hubei province carried out investigation on the previous suspected cases and revised the diagnosis results, and diagnosed the new patients according to the new diagnosis classification. In order to be consistent with the classification of case diagnosis released by other provinces in the country, since February 12, 2020, the number of clinically diagnosed cases in Hubei province has been included in the number of confirmed cases for publication.

2) The incremental confirmed cases in January 19, 2020 were 0.

Here, the above two days are outliers and are eliminated in correlation analysis and regression analysis.

2.2 Selection of statistical methods

(1) Correlation analysis

Pearson correlation coefficient, Spearman rank correlation coefficient and Kendall Rank determination correlation coefficient are commonly used in the correlation analysis for binary variables. The calculation method of Spearman rank correlation coefficient is as follows.

The calculation formula is as follows:

$$r = 1 - \frac{6 \sum_{i=1}^n (R_i - Q_i)^2}{n(n^2 - 1)} \quad (\text{Eq.1})$$

Research shows that under the hypothesis of normal distribution, Spearman rank correlation coefficient and Pearson correlation coefficient are equivalent in efficiency. In this research, it sets confidence level $p = 0.05$, $CI = 95\%$.

The value range of correlation coefficient r is equal and greater than -1 , equal and lower than 1 . $r > 0$ is positive correlation, $r < 0$ is negative correlation; $0.3 < |r| < 0.5$ is low degree linear correlation; $0.5 < |r| < 0.8$ is significant linear correlation; $|r| > 0.8$ for significant linear correlation; $|r| = 0$ indicates no linear relationship; $|r| = 1$ expresses full linear correlation.

(2) Linear regression

On the basis of correlation analysis, we estimate the parameters in the regression using the Ordinary Least Square (OLS) method. Incremental cases and four meteorological parameters are further selected for unary linear regression. All regressions are performed with the code SPSS v15.

The prediction model of linear regression is:

$$Y_t = aX_t + b \quad (\text{Eq.2})$$

In the formula,

X_t represents the period t independent variable;

Y_t represents the dependent variable of period t ;

a and b represent the parameters of a linear regression equation. Obtained by the following formula:

$$b = \frac{\sum Y_i}{n} - a \frac{\sum X_i}{n} \quad (\text{Eq.3})$$

$$a = \frac{n \sum x_i Y_i - \sum x_i \sum Y_i}{n \sum x_i^2 - (\sum x_i)^2} \quad (\text{Eq.4})$$

For the regression analysis of quantitative data, four prerequisites must be met: the linear relationship between incremental cases (dependent variables) and certain meteorological parameters, and each parameter is independent of each other, the residual of incremental cases satisfies the normality, and the residual of incremental cases satisfies the homogeneity of variance.

If linear regression results cannot be obtained, generalized linear regression is considered.

3 Results

3.1 Basic statistics of incremental cases and meteorological parameters

Table 1 summarizes the basic statistical results of incremental cases and meteorological parameters. As of March 20, 2020, the minimum number of incremental cases in Hubei province was 13 and the maximum was 4810, which occurred on February 13, 2020. From January 1st, 2020 to March 10, the average air pressure range is 1006.0-1031.2 hPa, the average is 1021.7hPa, the standard deviation is 5.1 hPa, and the fluctuation range is small. The average wind speed ranges from 0 to 5.0 m/s and the fluctuation range are small too. The maximum rainfall is 38.9mm, which occurs in January 9, 2020 and has no obvious regularity. The average temperature, the maximum temperature and the minimum temperature are 6.9 °C, 11.6 °C and 3.4 °C respectively, the standard deviation of the maximum temperature is 5.0 °C > that of the minimum temperature 4.3 °C > that of the average temperature 4.0 °C. The average water vapor pressure and the average RH are both related to the water loading in the air, and the mean \pm standard deviations are 8.3 ± 2.4 (hPa) and 83.0 ± 8.2 (%), respectively. Ultraviolet intensity is not the routine monitoring items in the meteorological station. Therefore, the daily total solar radiation and the maximum solar irradiance are selected as two auxiliary parameters, and their mean values are 757.7 (0.01 MJ/m²) respectively and 456.6 (W/m²), the standard deviations are 587.3 (0.01 MJ/m²) and 274.2 (W/m²), respectively. Obviously, the volatility of the values is very strong.

Figure 1 shows the frequency statistics of incremental cases and meteorological parameters, among which the normality of average air pressure, average temperature, minimum temperature, average relative humidity and average wind speed is better. The total solar radiation and the maximum solar irradiance present a saddle-shaped bimodal structure.

Figure 2 shows the tendency of incremental cases, average temperature, average water pressure and the maximum solar irradiance changing with time. Obviously, incremental cases-time pair is a single-peak structure. As for average temperature-time pair, it can be seen that there is a fluctuating process after about January 10, 2020. As for average water vapor pressure-time pair, after January 10, 2020, also has a fluctuating process, but the trend is relatively gentle. However,

there are two parallel tracks for the maximum solar irradiance-time pair, the general trend is to rise, but the trend is gentle.

3.2 Correlation Analysis between incremental cases and meteorological parameters

Table 2 summarizes cross-relationship between Hubei delta number with weather parameters. Under the condition of confidence interval 95% (95% CI), incremental cases in Hubei province have significant correlation with four meteorological parameters: average air pressure, average temperature, minimum temperature and average water vapor pressure. among them, there is a positive correlation with the average air pressure ($P = 0.010$), and the correlation coefficient $r = +0.358$, which belongs to low degree linear correlation. Negative correlation indexes include average temperature ($P = 0.029$), minimum temperature ($P = 0.013$), average water pressure ($P = 0.020$), correlation coefficient $r = -0.306, -0.347, -0.326$. From this, it can be judged that the increment of cases will be inhibited by the increase of temperature and water vapor loading. At the same time, the increase of average air pressure may increase the reproduction rate of the virus. In addition, the maximum temperature, RH and incremental cases are also negatively correlated, but the significance level is insufficient.

Figure 3 shows the curve fitting of HB_DeltaN with average pressure, average temperature, minimum temperature and average water vapor pressure.

3.3 Regression analysis of incremental cases and meteorological parameters

Table 3 shows the parameter estimates in regression model summary. Through parameter selection in the way of entering in sequence, finally only the minimum temperature and incremental cases can form a statistically significant linear regression equation ($P = 0.033$), and the equation is as follows:

$$\text{HB_DeltaN} = 1348.425 - 72.470 \times \text{Min_Temp} \quad (\text{Eq.5})$$

Thus, if Min_Temp increases by 1 °C, HB_DeltaN will decrease by 72.470 units on average. In other words, the result shows that the minimum temperature changes by 1 degree, and 72 incremental cases will change in the opposite direction. Let HB_DeltaN = 0, and get $\Delta \text{min_temp} = 18.6$ degrees, therefore, it rises 18.6 degrees on the basis of the mean value of 3.4 °C of the minimum temperature, that is, if the mean value of the minimum temperature reaches 22 °C, case increment shrink to zero.

Figure 4a shows the normality of the residual of incremental cases satisfies.

Figure 4b shows the homogeneity of variance for the residual of incremental cases.

4 Discussions

4.1 Discussion on statistical methods

(1) Pearson correlation coefficient, Spearman rank correlation coefficient and Kendall correlation coefficient are commonly used in the correlation analysis of binary variables. Pearson linear correlation coefficient requires that the values of continuous variables obey normal distribution. The correlation among variables, classifications or grade variables that do not obey normal distribution can be described by Spearman rank correlation coefficient. Since the cases are all continuous data, but they cannot be guaranteed to obey normal distribution, Spearman rank correlation coefficient is selected to describe them. Research shows that under the hypothesis of normal distribution, Spearman rank correlation coefficient and Pearson correlation coefficient are equivalent in efficiency.

(2) Time series method, commonly used in seasonal and repeatable viral infectious diseases. Because the 2019-nCoV is a sudden infectious disease, time series analysis cannot be considered (Gurgel et al., 2016; Yusef et al., 2007).

(3) Unary linear regression prediction is a method to establish the linear regression equation of X and Y for prediction according to the correlation between independent variable X and dependent variable Y. If linear regression results cannot be obtained, generalized linear regression is considered. The extension of the linear model of the generalized linear model is to establish the relationship between the mathematical expectation value of the response variable and the prediction variable of the linear combination through the link function. Its feature is that it does not forcibly change the natural measurement of data, and the data can have nonlinear and non-constant variance structure, it is a development of linear model when studying non-normal distribution of response value and simple and direct linear transformation of nonlinear model. However, linear regression results are easy to explain natural processes of respiratory infectious diseases caused by viruses and are of great significance. (Kim et al., 2016; Lim et al., 2012; Souza et al., 2012; Onozuka et al., 2009).

In this study, the correlation analysis between 10 meteorological parameters and case

increment was introduced, and finally 4 parameters were found to have strong correlation with case increment. Considering the three-month statistical cycle, the actual valid data is only 53. In the case of limited observations, there can be 4 parameters with obvious correlation. We have every reason to believe that, first, with the increase of effective observations, the statistical correlation between parameters will gradually appear; secondly, case increment is very sensitive to meteorological parameters, and analyzing cases with meteorological parameters is an effective method; thirdly, in addition to the minimum temperature, the other three parameters cannot establish a linear regression equation. Similarly, this study also uses the method of multiple linear regression analysis, but the overall fitting degree is very poor, the ultimate reason, it is not the problem of statistical method itself, but the effective observations for sudden infectious diseases is too little and the law is not obvious. 2019-nCoV evolution to seasonal infectious disease such as influenza virus is possible, if this happens, then periodic and repetitive data can be accumulated; meanwhile, this study finds that meteorological parameters, such as the minimum temperature and the average water vapor pressure, are the specific influencing factors of 2019-nCoV, this will become very meaningful for predicting the 2019-nCoV epidemic trend in the future.

In addition, if regression analysis is to be carried out between temperature and RH and the number of cases (whether cumulative or incremental), taking into account the correlation between independent variables, either the Durbin-Watson Test ($0 < \text{Durbin-Watson} < 4$) must be passed, or the random forest model must be used. The advantage of random forests is that they do not need a pre-specified model to evaluate like regression models, and can process interactive variables with correlation.

(4) Although incubation period has influence on correlation analysis and regression equation establishment, 2019-nCoV is a new type of virus. Its incubation period data is limited and there is great uncertainty. According to the data of 10 cases, a study shows that the average incubation period of n2019-nCoV is 5.2 days, CI 95%: 4.1 ~ 7.0. (Li et al.,2020). The incubation period is relatively long. The incubation period based on the data of 10 cases is inaccurate. Therefore, no choice was made to include the incubation period in the study. In addition, without adding incubation period parameters, the relationship between meteorological factors and virus onset will not be affected, and the research results will not be affected.

4.2 Relationship between COVID-19 epidemic and climate characteristics of Hubei province

The influence of changes in meteorological parameters brought by seasonal replacement on COVID-19 and the development and outcome of epidemic situation are the focus of attention of all people in the world. COVID-19 outbreak in Hubei Province in 2019 shows obvious characteristics related to meteorological factors that have not been reported.

We summarize the daily incremental cases and meteorological factors of COVID-19 in Hubei province by using the correlation analysis of Spearman's rank correlation coefficient. It is found that the average temperature, minimum temperature, water vapor pressure and air pressure are significantly correlated with the daily increase of COVID-19 cases. The atmospheric pressure is positive correlation. The other three are negatively correlated with the delta. The linear relationship between the incremental cases and the minimum temperature is regained by using the linear equation. As far as we know, these results are reported for the first time.

It is generally believed that seasonality is the manifestation of respiratory diseases related to meteorological factors. At present, MERS is considered to be seasonal (Nassar et al., 2018), and meteorological factors (high temperature, high ultraviolet index, low wind speed and low RH) are also found to be the cause of the increase in MERS-CoV cases (Altamimi et al., 2019). Research on the relationship between meteorological factors and SARS shows that the number of daily cases is negatively correlated with the highest and/or lowest temperatures and the air pressure is positively correlated with SARS transmission (Bi et al., 2007). Temperature, RH and wind speed are the three key meteorological factors (Cai et al., 2007) that affect the spread of SARS, but seasonal problems cannot be analyzed because SARS occurred only once.

Among the viral respiratory tract infections, the most frequently studies related to meteorological factors are RSV, a common respiratory virus. RSV accounts for 20-25% of respiratory infections in children and 3-7% in adults and the elderly. Previous studies have found that, in tropical, subtropical and temperate regions, RSV infections are related to meteorological factors such as temperature, RH, atmospheric pressure and rainfall (Zhang et al., 2020; Darniot et al., 2018; Gurgel et al., 2016; Tian et al., 2017; Sirimi et al., 2016; Liu et al., 2016; Chen et al., 2014; du Prel et al., 2009). The increase of RSV cases is negatively correlated with RH (Gurgel et al., 2016; Tian et al., 2017; Liu et al., 2016). Similarly, due to the high incidence rate of influenza virus, it brings heavy medical burden and has been fully studied. The results show that influenza virus (including A, B, etc.) is obviously related to meteorological parameters (temperature, ultraviolet

index, wind speed, RH, etc.) (Yu et al., 2013; Soebiyanto et al., 2010; Tamerius et al., 2019; Chong et al., 2019; Peci et al., 2019; Jaakkola et al., 2014).

The geographical location of Hubei province is between NL 29 degrees 05 minutes ~33 degrees 20 minutes and EL 108 degrees 21 minutes -116 degrees 07 minutes, which mainly belongs to subtropical monsoon climate, it is characterized by transition from subtropical to temperate. The average temperature in the whole province is 15-17 °C, the coldest in January, the average temperature in most areas is 3-6 °C, and the hottest in July, the average temperature is 27-29 °C. Due to the huge thermal difference between the sea and land, the cold and high pressure of Siberia-Mongolia in winter and the hot and low pressure of Indian monsoon in summer are formed on the ground barometric field, which makes the prevailing wind direction on the ground generate periodic conversion accordingly. Winter monsoon is cold and dry, resulting in low temperature and less precipitation in winter. In summer, the southward wind blowing from the ocean to the mainland prevails, which is warm and moist, resulting in cold and dry winter, hot and rainy summer and frequent meteorological disasters.

According to the report of Huang CL, et al, Wuhan Jin Yin-tan Hospital has received a series of pneumonia cases of unknown on December 2019 (Huang et al.,2020). By January 2020, the whole Hubei province was under the condition of the lowest temperature and humidity throughout the year. Unfortunately, the temperature and water vapour pressure were negatively correlated with the 2019-nCoV increment, which was conducive to the survival and transmission of 2019-nCoV. If the epidemic occurs in July 2019, the most likely result is that the intensity of the epidemic will be greatly weakened and the duration will be shorter. In a sense, the epidemic is a derivative of meteorological disasters.

4.3 Two meteorological parameters related to moisture in air

We first observed that 2019-nCoV has significant correlation with the average minimum temperature, water vapor pressure, and atmospheric pressure. The average minimum temperature has a negative interference effect on the stability and transmission of 2019-nCov, which may directly affect the incidence of COVID-2019. The minimum temperature increased by 1 ° C, and the number of newly diagnosed patients in Hubei dropped by an average of 72.470 units. We deem

that under subtropical monsoon conditions, water vapor pressure is more sensitive to RH than 2019-nCov.

The research results show that the average water vapor pressure and RH are both negatively correlated with the case increment, but the significance level of RH is insufficient, or in other words, in statistical significance, correlation is not very credible.

Relative humidity (f) is the ratio of the actual water vapor pressure in the air to the saturated water vapor pressure at the same temperature (expressed as a percentage), that is relative humidity directly reflects the degree of air saturation.

$$f = \frac{e}{E} \times 100\% \quad (\text{Eq.6})$$

When $f = 100\%$, the air has reached saturation, when unsaturated, $f < 100\%$, when over saturated, $f > 100\%$. the magnitude of RH is not only related to the moisture content in the atmosphere, but also decreases with the increase of temperature. When the water vapor pressure remains unchanged, the temperature rises, the saturated water vapor pressure increases, and the RH decreases. Therefore, there is a correlation between temperature and RH, and the two are inter-dependent variables.

There has always been opposition to the occurrence and epidemic of virus (influenza) by water vapor pressure and RH (Prussin et al., 2018). Water vapor pressure describes the mass of water vapor per unit of air (i.e. AH), while RH describes the ratio of actual concentration of water vapor to the maximum possible concentration, this ratio varies with temperature. Studies have shown that the relationship between water vapor pressure and RH is significant (Shaman & Kohn, 2009). According to their analysis, water vapor pressure explained 50% and 90% of influenza virus transmission and survival variability respectively, while RH explained 12% and 36% of variability respectively. In the study of establishing influenza-related mortality model, it is found that the change of water vapor pressure is the root cause of seasonal trend, while RH prediction is relatively insufficient (Shaman et al., 2010). It is also reported that AH (water vapor pressure) is better than RH in virus inactivation. Causal Analysis of Global Influenza incidence data shows that water vapor pressure is a stronger driver than RH (Deyle et al., 2016).

In epidemiological studies, seasonal and metering conditions of influenza were compared, and the results showed lower temperature and water vapor pressure can increase the survival and

transmission of influenza virus in temperate regions (Shaman & Kohn, 2009; Shaman et al., 2010 & 2011; Kolberg et al., 2019). Studies from China also prove that influenza virus is negatively correlated with temperature and water vapor pressure (Cao et al., 2010; Sun et al., 2018; Yang et al., 2019; Su et al., 2020). The average water vapor pressure in sub-cold zone climate is lower than 4 hPa, which may trigger the occurrence of influenza (Kolberg et al., 2019). Studies in tropical/subtropical regions of China have found that, water vapor pressure is negatively correlated with the incidence of A/dnan1pdm09 (Influenza A) and Yamagata (Influenza B) (Pan et al., 2019).

This study argues that it is because RH is related to both the water vapor pressure and the temperature, and the annual changes are relatively complex so the changes of time in the past study included one year or many years, and meteorological parameters including different seasons (range is larger). However, in our study because the effective time period was for 51 days, and in the epidemic area, the range of average minimum temperature was 18.10 °C (-3.6 ~ 14.5°C), the regression coefficient with statistical significance cannot be obtained, but the correlation analysis shows that it has positive and negative correlation with the average temperature, water vapor pressure and atmospheric pressure. In other words, the increment of cases is less sensitive to relative humidity. According to the data analysis results of the epidemic situation in Hubei province, under the subtropical monsoon climate conditions, the RH cannot be selected, and the vapor pressure should be selected as the parameter to analyze the influence relationship between the moisture in the air and the activity of the case.

We demonstrate for the first time the epidemiological correlation between water vapor pressure and respiratory tract infection virus-2019-nCoV other than influenza. In coronavirus(SARS-CoV, MERS-CoV) and RSV have not been reported to be associated with water vapor pressure. According to its related mechanism analysis, Sundell et al., believes that, as for the relationship between climatic factors and viral respiratory epidemiology, in temperate climate, non-coated viruses (HRV and HEV) when causing infection, may be transmitted through large drops or close contact rather than through small atomized particles, so the dependence of transmission factors on meteorological factors is relatively small (Sundell et al., 2016). Previous studies have shown that the envelope (E) protein of coronavirus that causes Severe Acute Respiratory Syndrome is directly related to viral toxicity (DeDiego et al.,2014; Castaño-Rodríguez

et al.,2018; Schoeman &Fielding,2019), our speculation that the envelope proteins closely related to 2019-nCov pathogenicity are sensitive to the average minimum temperature and water vapor pressure (negative correlation), and they are more dependent on climatic factors, especially temperature (including average temperature and minimum temperature). This finding should have theoretical significance for viral respiratory infectious diseases with abundant meteorological factors, and of course need more evidence to support it in the future.

4.4 Relationship between case increment and atmospheric pressure

Previous studies believe that atmospheric pressure is positively correlated with influenza virus (Li et al., 2015; Soebiyanto et al., 2010). Atmospheric pressure may be the driver of influenza (Sundell et al.,2016). RSV activity increases with the increase of atmospheric pressure (Hervás et al.,2012). An analysis of the relationship between the meteorological factors of 9 cities with different climate types in the United States and the activity of RSV shows that in Delhi, air pressure is the main related factor of the total amount of RSV, it was associated with 22% of RSV activity (Yusuf et al.,2007). The cause of influenza may be that nasal mucosa is easy to rupture under dry conditions and high pressure in winter, so it is easy to be infected with virus. However, the detailed mechanism needs further study (Su et al.,2020).

4.5 Shortcomings

This study has some limitations.

First, studies have shown that COVID-19 has a certain incubation period [average incubation period is 5.2 days, 95% CI: 4.1 ~ 7.0], but this estimation is based on 10 cases, more information support must be provided. The COVID-19 in Hubei province belongs to sudden acute infectious disease, and the pathogen has not yet been determined. The relevant information we have obtained does not have the presumed incubation period parameter (lag effect). Before January 17, Wuhan released the number of intermittent cases, but it was not a daily statistical result, which did not meet the requirements of the basic data collection designed by our research. At the same time, our collection range of cases started from January 17, covering 53 days. By March 10, the incidence of cases in Hubei province decreased. The collection date of cases has covered most of the basic process of occurrence and development in Hubei province. This content should be added to the analysis of relevant factors for further summarizing and analyzing the incidence of epidemic cases in Hubei province in order to make the research more accurate and scientific.

Secondly, we have examined the correlation studies between 10 meteorological indicators and case increment respectively, average atmospheric pressure, Average temperature, average minimum temperature, average water pressure and case increment have significant correlation. We believe that atmospheric pressure, temperature and water vapor pressure are crucial to shaping conditions conducive to the diffusion of 2019-nCoV aerosol, but in the epidemiological model, whether they should be treated as individual factors or as an associated entity remains to be further studied. Unary linear regression analysis was carried out on average atmospheric pressure, average temperature, average minimum temperature, average water pressure and case increment respectively, and a statistically significant regression equation was obtained. However, there is no statistically significant binary linear regression equation describing two factors. We need further research, such as the correlation between the onset of viral respiratory tract infection under the combined action of minimum temperature and water vapor pressure.

Third, we cannot exclude the possible effects of some mixed factors, such as population flow and air pollution, which may affect the number of diseases and further deviate our results. In addition, we did not consider host factors, such as immunity or vulnerability, which play a role in disease transmission. A large number of studies have shown that viral activity that causes respiratory infectious diseases is sensitive to climate. Climatic factors may affect the survival and transmission of the virus in the environment, host susceptibility and exposure possibility. We found that 2019-nCoV showed significant role in meteorological factors during the outbreak of the COVID-19 in Hubei province, but we are also very clear, as scholars have agreed, meteorological parameters can only explain no more than 30% changes in influenza activity (Monamele et al., 2017), there are still many problems about 2019-nCoV to be confirmed.

Social distancing measures are essential components of the public health response to COVID-19. The purpose of these mitigation measures is to reduce transmission, thereby delaying the peak of the epidemic, reducing the total number of infected people, and spreading new cases over a longer period of time to relieve the pressure on the health care system and achieve the purpose of controlling the epidemic (Fong et al., 2020). The corresponding measures taken in Wuhan and Hubei Province have already seen practical results.

5 Conclusions

First of all, in January of every year, the overall temperature and humidity of Hubei province are at the lowest level of the whole year, and it is precisely in this month that the COVID-19 erupts on a large scale. Using the correlation analysis of Spearman, the average atmospheric pressure, average temperature, minimum temperature and average water vapor pressure are significantly correlated with the daily increase of cases of COVID-19. The time range is January 1 to March 10, 2020, and meteorological factors (parameters) are provided evidence of correlation with the incidence of COVID-19. Obviously, different indicators of climatic factors may completely affect the occurrence of the 2019-nCoV epidemic, and the outbreak of the 2019-nCoV is not accidental in time. Although this conclusion is derived from the process of COVID-19 confirmed case evolution in Hubei province of China, they still show that various results are compatible within the current knowledge range of the epidemic of 2019-nCoV. The meaning of this work is: (1) The decline in prevalence rate may be affected by the changes in meteorological factors that constrain viral transmission capacity; (2) climate change may slow down the rate of pandemic. Therefore, as for predicting epidemic scale and formulating prevention and control strategies in the process of 2019-nCoV global transmission, differences in meteorological factors should be taken into account, which will provide better preparation for the health care system worldwide; (3) As of March 10, 2020, a total of 67,773 confirmed cases had been reported in Hubei province, which was the worst-affected area in the world at that time. Our study has authority and credibility.

Second, average atmospheric pressure, average temperature, minimum temperature and average water pressure may affect the development of epidemiological epidemic caused by 2019-nCoV. We analyzed from epidemiological statistics, the possible association of meteorological factors to the onset of COVID-19, and the influence of meteorological parameters on virus transmission and survival from virus causing respiratory diseases and explained the mechanism. On the basis of previous studies, the interaction theory of meteorological factors on the epidemic process of viral respiratory infectious diseases has been enriched and developed. In particular, for the first time, we have proved the epidemiological correlation between water vapor pressure and the COVID-2019, an extra-influenza respiratory tract infection (a new respiratory tract infection). We speculate that compared with non-coated virus, coated virus-2019-nCoV is more significant on climatic factors, especially temperature (including average temperature and minimum temperature). Previous studies have paid little attention to the effect of atmospheric

pressure on viral respiratory infectious diseases. This study shows that there is a positive correlation between atmospheric pressure and the daily increase in the number of cases in 2019-nCoV, refreshing the cognition of the influence of meteorological factors on viral infectious diseases.

Third, meteorological factors may affect the outcome of epidemiological epidemic caused by 2019-nCoV. Our research uses unary linear equation to explicate the linear relationship between incremental cases and the minimum temperature. The results show that the minimum temperature changes by 1 degree, and the incremental cases will change by 72 cases in the opposite direction, it can be predicted that the minimum temperature in Hubei province reaches 22 °C, and the result of case increment is zero, which provides reference for the prevention, control and prediction of the epidemic situation of 2019-nCoV.

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Supporting information

Supplementary information contains an Excel file with datasheet containing the meteorological observatory data and number of confirmed cases from January 1, 2020 to March 10, 2020 in Hubei province of China.

Data accessibility

The data produced in this study can be found in the Supplementary information. The datafile includes an Excel file and a Word file which describes the data.

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Table 1 Basic statistical analysis of HuBei delta number and weather parameters

		HB_Delt aN	Ave_Pre (HPa)	Ave_Temp (°C)	Max_Temp (°C)	Min_Temp (°C)	Ave_WV P (HPa)	Ave_RH (%)	Ave_WS (m/s)	Prep (mm)	Tot_SR (0.01 MJ / m ²)	Max_SI (W / m ²)
N	Valid	51	68	68	68	68	68	68	68	68	68	68
	Missing	18	1	1	1	1	1	1	1	1	1	1
Mean		1062.67	1021.7103	6.9485	11.5500	3.4132	8.3397	83.0735	1.4765	3.5015	757.6912	456.5882
Std. Error of Mean		153.303	.61863	.49161	.60299	.51703	.29186	.99081	.10943	1.04014	71.22281	33.25677
Std. Deviation		1094.806	5.10134	4.05391	4.97242	4.26352	2.40672	8.17042	.90242	8.57717	587.31830	274.24236
Range		4810	25.20	17.50	21.90	18.10	10.20	37.00	5.00	38.90	1787.00	866.00
Minimum		13	1006.00	1.20	3.00	-3.60	5.10	59.00	.00	.00	65.00	45.00
Maximum		4823	1031.20	18.70	24.90	14.50	15.30	96.00	5.00	38.90	1852.00	911.00
Percentiles	25	134.00	1020.2250	3.7000	7.6750	.2000	6.3750	78.2500	.9000	.0000	221.5000	182.5000
	50	570.00	1022.2500	6.0500	11.4500	3.1500	7.8500	84.0000	1.3000	.0000	562.0000	426.5000
	75	1921.00	1024.7250	9.8500	15.0000	5.8000	9.2000	89.0000	1.9000	1.6750	1330.7500	710.0000

Ave_WVP (HPa)	Correlation Coefficient	-.326*	-.632**	.885**	.510**	.873**	1.000	.194	.179	.234	-.144	-.033
	Sig. (2-tailed)	.020	.000	.000	.000	.000	.	.113	.145	.054	.241	.789
	N	51	68	68	68	68	68	68	68	68	68	68
Ave_RH (%)	Correlation Coefficient	-.038	-.189	-.239*	-.540**	.093	.194	1.000	.369**	.622**	-.701**	-.634**
	Sig. (2-tailed)	.793	.122	.050	.000	.452	.113	.	.002	.000	.000	.000
	N	51	68	68	68	68	68	68	68	68	68	68
Ave_WS (m/s)	Correlation Coefficient	-.156	-.244*	.005	-.248*	.245*	.179	.369**	1.000	.599**	-.588**	-.518**
	Sig. (2-tailed)	.275	.045	.966	.042	.044	.145	.002	.	.000	.000	.000
	N	51	68	68	68	68	68	68	68	68	68	68
Prep (mm)	Correlation Coefficient	-.232	-.232	-.049	-.315**	.255*	.234	.622**	.599**	1.000	-.599**	-.483**
	Sig. (2-tailed)	.102	.057	.693	.009	.036	.054	.000	.000	.	.000	.000
	N	51	68	68	68	68	68	68	68	68	68	68
Tot_SR (0.01 MJ / m ²)	Correlation Coefficient	.047	.118	.157	.624**	-.277*	-.144	-.701**	-.588**	-.599**	1.000	.919**
	Sig. (2-tailed)	.744	.338	.201	.000	.022	.241	.000	.000	.000	.	.000
	N	51	68	68	68	68	68	68	68	68	68	68
Max_SI (W / m ²)	Correlation Coefficient	.034	.030	.242*	.630**	-.165	-.033	-.634**	-.518**	-.483**	.919**	1.000
	Sig. (2-tailed)	.813	.806	.047	.000	.180	.789	.000	.000	.000	.000	.
	N	51	68	68	68	68	68	68	68	68	68	68

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Table 3 Model Summary and Parameter Estimates

Dependent Variable	Independent variable	Parameter Estimates		Equation Expression	Durbin-Watson	P
		Constant	b			
HB_DeltaN	Min_Temp	1348.425	-72.470	HB_DeltaN=1348.425-72.470xMin_Temp	0.353	0.033

Figure Captions

Figure 1 includes 11 sub-figures. (a) demonstrates the frequency statistics of incremental cases in Hubei province; (b)-(k) demonstrates the frequency statistics of average pressure, average temperature, maximum temperature, minimum temperature, average water vapour pressure, average relative humidity, average wind speed, precipitation, total solar radiation, maximum solar irradiance

Figure 2 includes 4 sub-figures. (a) to (d) shows the tendency of incremental cases, average temperature, average water pressure and the maximum solar irradiance changing with time

Figure 3 includes 4 sub-figures. (a) to (d) shows curve fitting results of HB_DeltaN with average pressure, average temperature, minimum temperature and average water vapour pressure

Figure 4a shows the normality of the residual of incremental cases satisfies. Figure 4b the homogeneity of variance for the residual of incremental cases

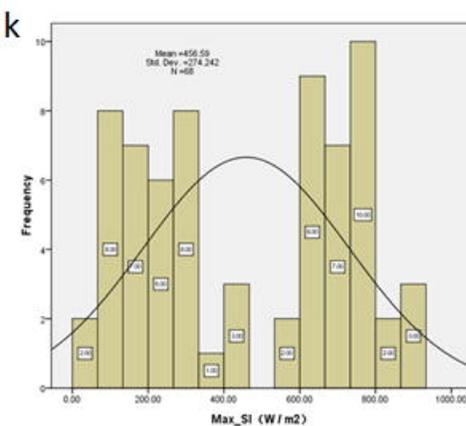
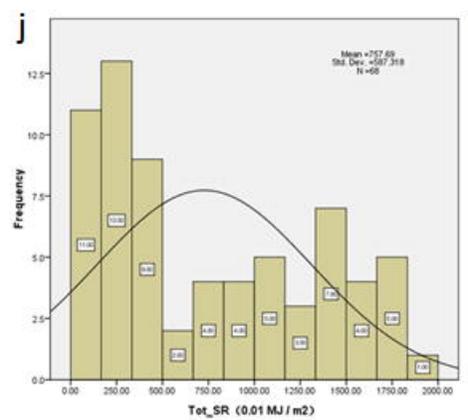
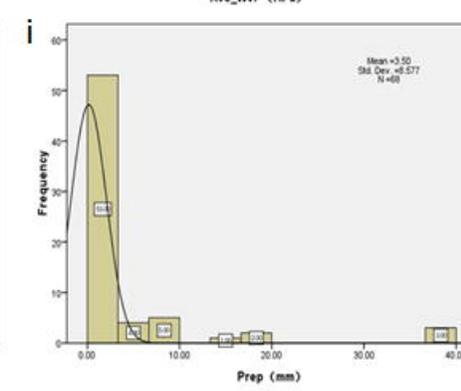
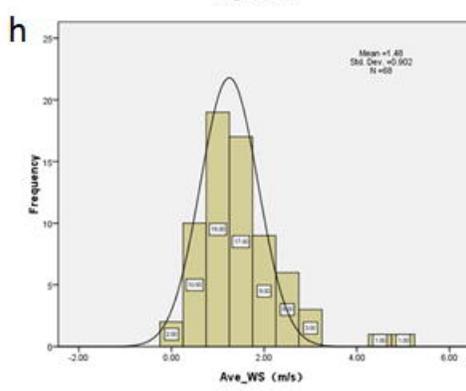
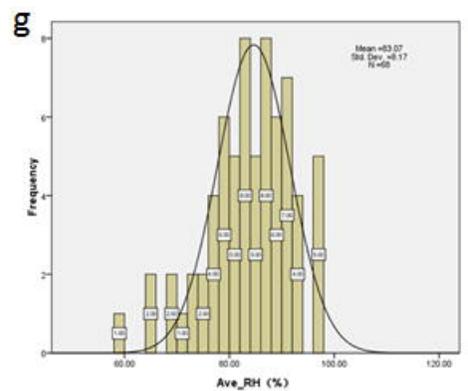
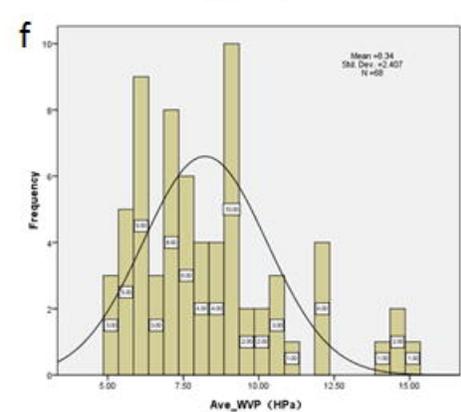
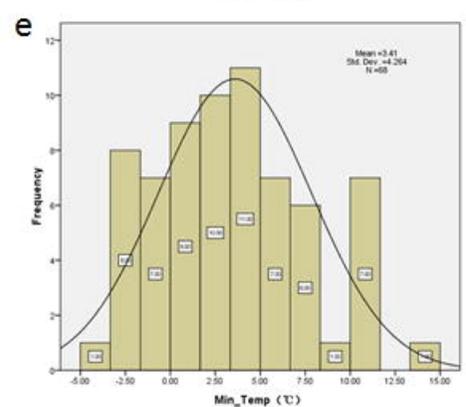
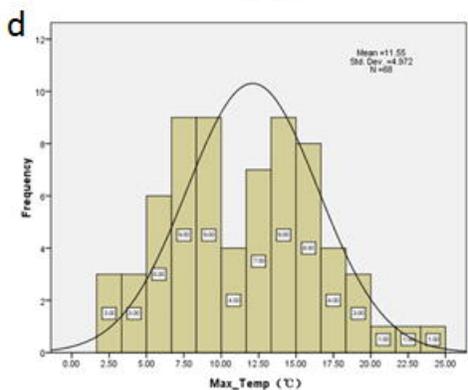
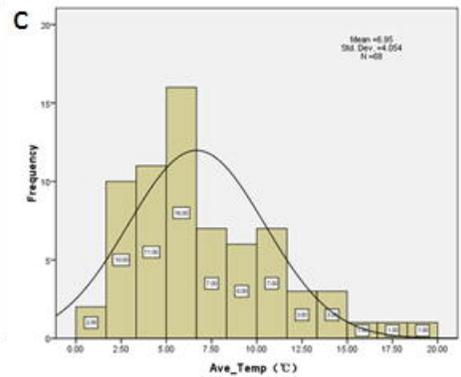
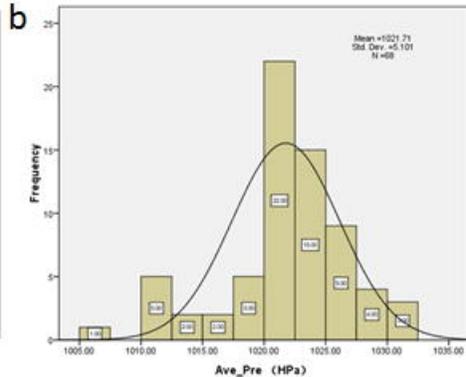
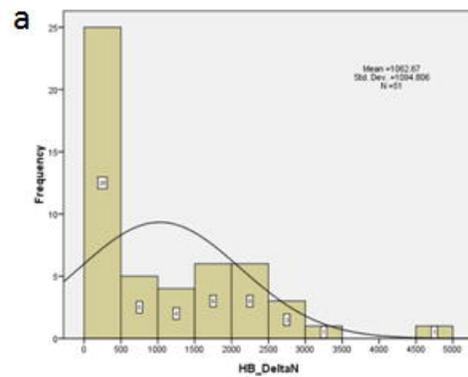
Supporting information-data description

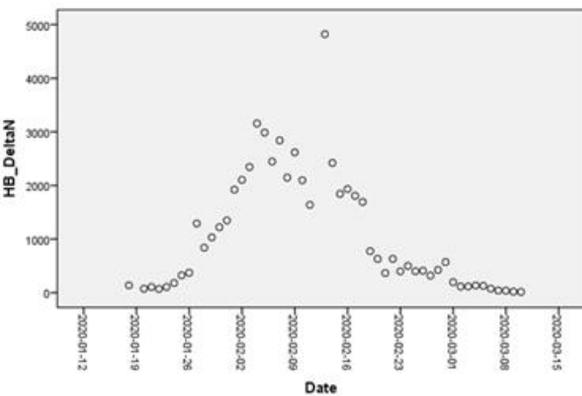
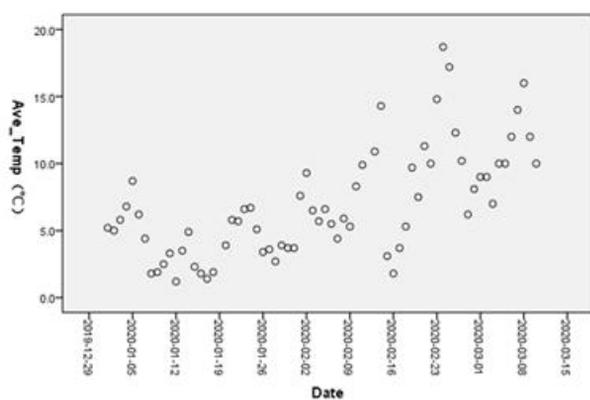
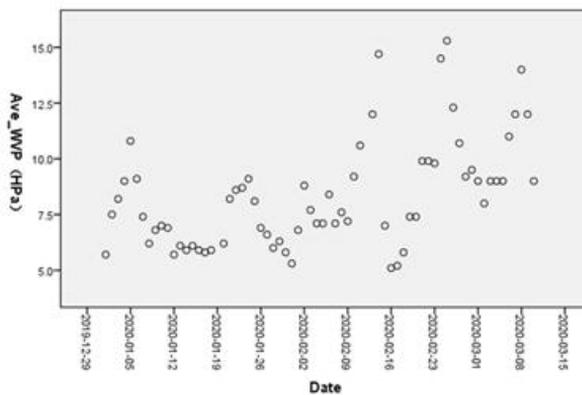
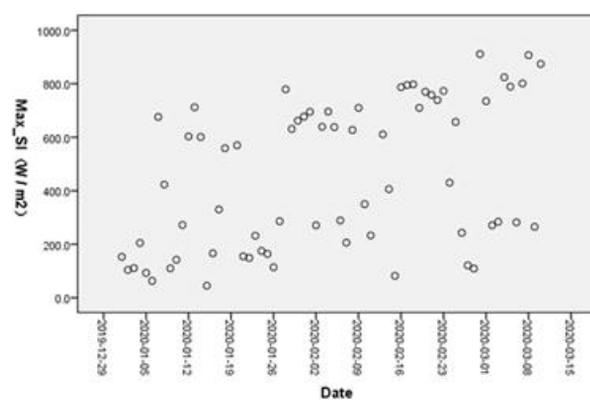
(1) Meteorological Observatory data

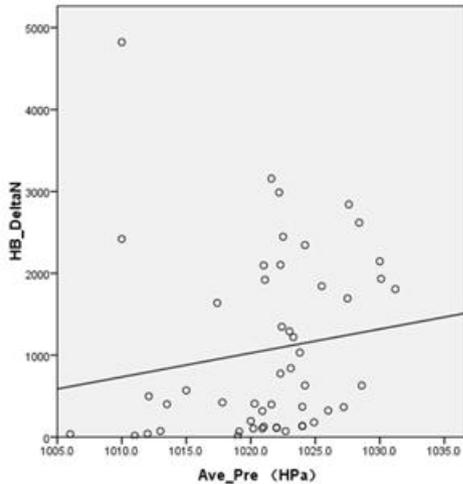
The available data period provided from the Meteorological Data Center of China Meteorological Administration is from December 1, 2019 to March 10, 2020 (100 daily meteorological data). The actual data selected starts on January 1, 2020 and ends on March 10, 2020. Meteorological observatory data include: average air pressure (hPa), average temperature (°C), maximum temperature (°C), minimum temperature (°C), average water vapor pressure (hPa) (equivalent to absolute humidity), average relative humidity (%), average wind speed (m/s), precipitation (mm), total solar radiation (0.01 megajoules/square meter), maximum solar irradiance (Watt/square meter). Afterwards, it uses Ave_Pre, Ave_Temp, Max_Temp, Min_Temp, Ave_WVP, Ave_RH, Ave_WS, Prep, Tot_SR and Max_SI to refer to them respectively.

(2) Number of confirmed cases

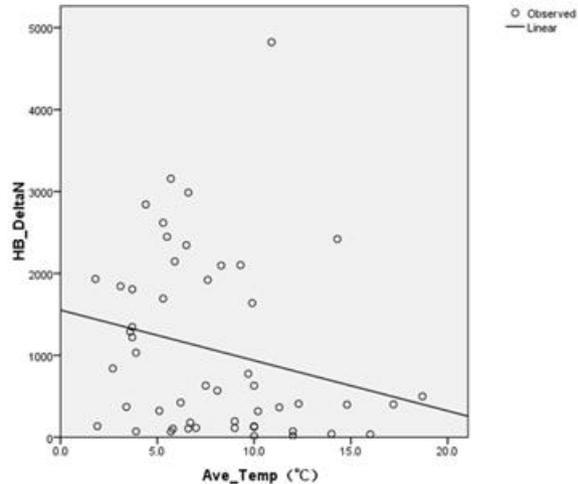
This study uses January 17, 2020 as the starting point of time to retrieve data. Case data include Hubei's cumulative confirmed cases, Hubei's cumulative death, and Hubei's incremental cases, namely HB_CumN, HB_CumD, and HB_DeltaN respectively. February 12, 2020 and January 19, 2020 are outliers.



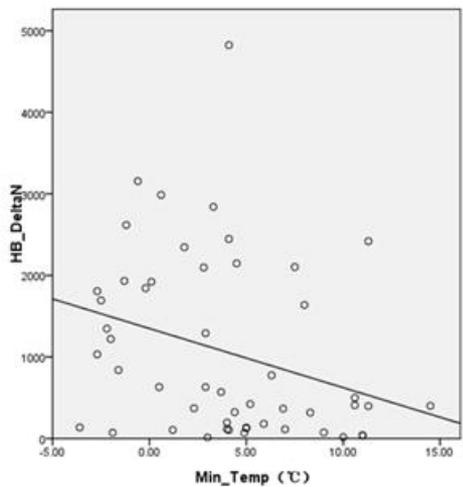
DeltaN Tendency**(a)****Temp Tendency****(b)****WVP Tendency****(c)****Max_SI Tendency****(d)**



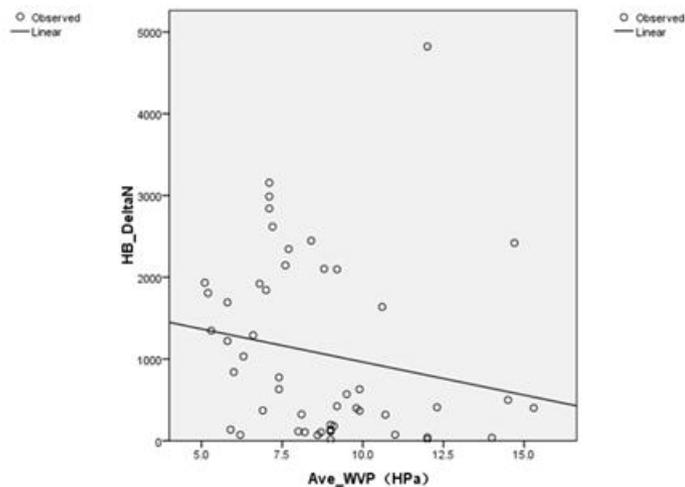
(a)



(b)

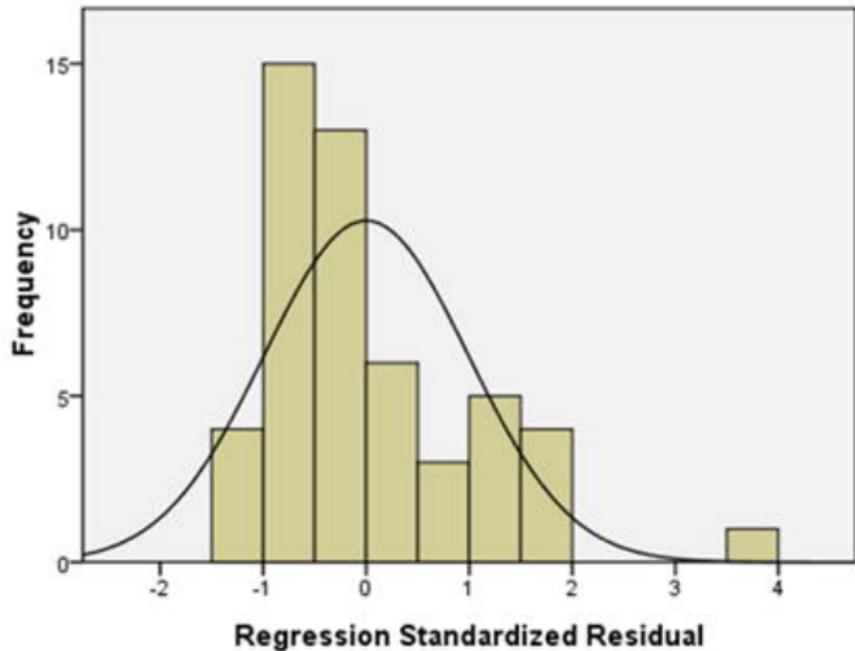


(c)



(d)

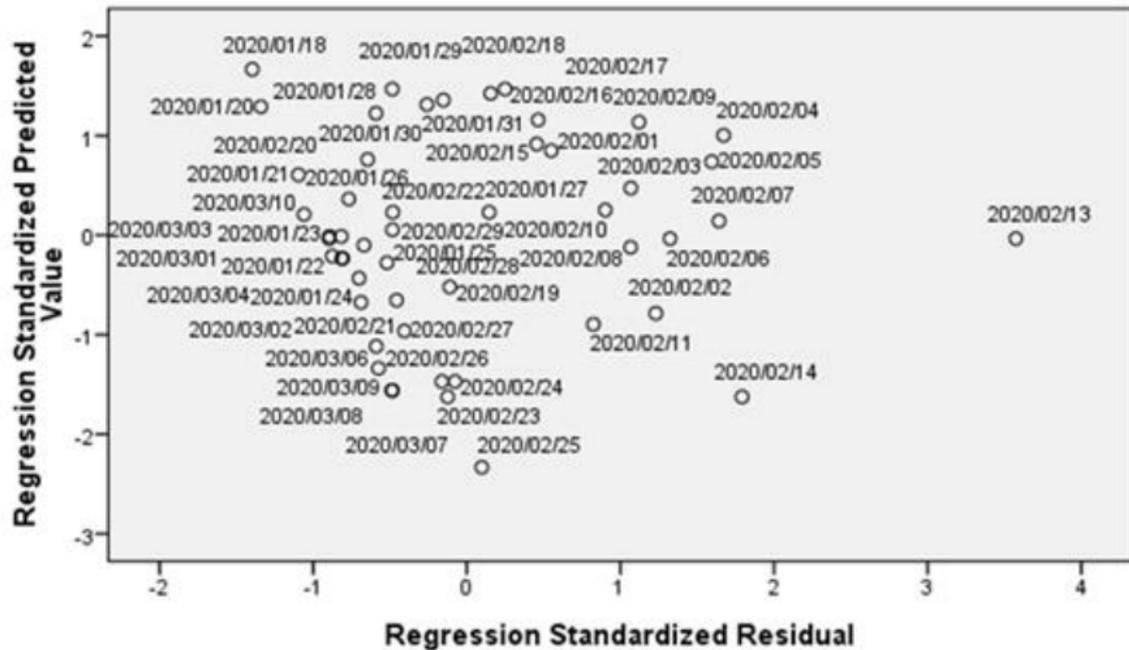
Dependent Variable: HB_DeltaN



(a)

Mean = -4.51E-17
Std. Dev. = 0.99
N = 51

Dependent Variable: HB_DeltaN



(b)