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Coronavirus Disease Incidence Resonance with Coastline Dynamics: An Evaluation on Global Resurgence of the Pandemic

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Abstract

Introduction: Many studies were done earlier to understand the role of climatic, environmental, and sociodemographic factors in the transmission, spread, and viability of SARS-CoV-2. *Objectives:* While there are principal climatic factors that influence the transmission and spread, specific factors such as latitude and water body mass are not critically examined. Therefore, this study aims to investigate the role of latitude and heat flux from water body mass in coastal environs on the resurgence and incidence of COVID. *Methodology:* A study was conducted examining the cases reported per million population, latitude degrees, and coastline length in two criteria groups ($n = 120$ and 10) spanning five geographic continental regions. The collected data were statistically analyzed to validate the three prepositions of the study. *Findings:* The cases reported per million population were least in countries lying below 25˚-degree latitude, and countries in this range have the mean highest coastline length. Our analysis in the $n = 120$ group reveals a moderate relationship among rises in cases with latitude degrees ($r = 0.425$, $p < 0.01$, $n = 120$) but is associated negatively with coastline length. From the top countries having the longest coastline length, the association among the variables reveals a weak relationship exists between cases and latitude ($r = 0.356$, $p = 0.312$, $n = 10$), while no correlation is observed with coastline length. *Novelty:* A rise in the incidence rate and the global resurgence of cases can be explained by previous researchers considering climatic variables and socio-demographic factors. However, other parameters, such as the latent heat of evaporation from water body mass in coastal zones in different latitudinal countries, on the incidence and resurgence patterns are examined in this study. Observations indicate that the disease incidence trend is not similar across all countries and that no single factor fully influences the rise in cases.

Keywords:
Coronavirus;
Flux;
Latent;
Latitude;
Transmission;
Aerosol;
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1- Introduction

Coronavirus disease has claimed over 6 million deaths globally, with the highest cumulative total deaths reported in the USA, followed by China and India [1]. The resurgence of infections from the outbreak of new variants has further aggravated the economic crisis globally and paralyzed industrial growth in many countries. The continued prevalence of the disease can be attributed to the SARS-CoV-2 mutation leading to new variants that are different from the first variant identified in Wuhan, China [2]. Some of these re-infections happened over a wide geographical area, implying that the reoccurrence of disease incidence has led to a new wave of infections. Studies on the role of climatic variables and environmental factors on the disease incidence and spread of the virus in different geographical regions indicate the need for studying them more intricately, especially considering the resurgence observed from the increased number of cases in many countries.

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Extensive research studies were conducted to assess the role of climatic and non-climatic factors on the transmission and spread of the virus in different geographical conditions [3], where climatic factors like air temperature, humidity, rainfall, and wind speed were observed to have positive and negative implications on COVID incidence and transmission to a variable extent in different regions [4–6]. Likewise, air pollutant emissions are also understood to facilitate the transmission and spread of the virus in highly populated environments, where there is a significant correlation found between COVID transmission and an increase in the incidence rate from air pollution [7, 8]. The effect of climate variables on COVID transmission in the United States and China shows that exposure to particulate matter is associated with an increase in fatality cases, as aerosols and particulate matter tend to act as carriers of several viruses [9, 10]. Among other environmental factors, the effect of carbon dioxide emissions on ambient temperatures has also favored COVID infections, with the increase in transmission and incidence rate probably a result of the indirect effect of environmental factors [11, 12]. Amnuaylojaroen & Parasin [13] report positive and negative associations between COVID transmission and air pollution-induced climate change.

Empirical studies also emphasize the influence of climatic and environmental parameters, together with socio-demographic factors contributing to transmission and the increase in incidence rate. It is also pertinent to note that climatic and environmental factors do not provide sufficient evidence for the resurgence of incidence in most cases, given that countries bordering coastal environments undoubtedly have affinity behind the resurgence. From our analysis of studies existing in the domain area, we have observed that coastal dynamics such as sea temperatures, wave currents, turbulence fluctuations from cyclones, typhoons, hurricanes, and daily tidal wave formations tend to interfere with the energy balance between different atmospheric entities, which could probably lead to a better understanding of the resurgence and increase in incidence rate in countries with coastal environments. Moreover, the role of sea surface temperature on latent heat flux in regional and global contexts was substantially investigated, along with the factors determining the latent heat flux over water bodies, which can explain the resurgence pattern among coastal habitats [14–17].

On the other hand, empirical studies show that COVID spreads principally through respiratory droplets and aerosols, both in internal and external environments. Zhao et al. [18], but the role of aerosol production from external environments is intriguing to investigate, and aerosol sources from a tidal wave and sea spray currents from coastal sea waters are significant topics to explore. Huang [19] explained the significance of ocean circulation in building differences in heat flow rates at different latitudinal ranges, similar to the studies published by Zhang & McPhaden [20]. There are studies related to sea spray aerosols and their dispersion phenomena in the atmosphere carrying infected respiratory droplets, in addition to a few study reports revealing that aerosol formation around the coastal zones is very prominent in populating their concentration and sustaining them for 2–6 hours [21, 22]. Besides, other studies report evidence of infectious disease transfer through aerosol transmission from the infected population [23], which also applies to SARS-CoV being a respiratory-related virus that is more likely to be present in aerosols transmitting the disease over short to long ranges [24–26].

SARS-CoV-2 tends to coagulate with sea spray aerosols, which inhibits their infection capacity through the dispersal of aerosol droplets. Such aerosol droplets tend to travel three times farther in low-temperature and high-humidity environments that are typically observed in coastal environments [18]. SARS-CoV was found to be detected in air samples, can lodge in aerosol droplets based on the amount of aerosol production rate, and further intensify the transmission through aerosol dispersion [27, 28]. Besides, there are considerable observations reported on the association between SARS-CoV-2 and aerosol particles emitted from different sources [29]. Substantiating the above claims, Reinmuth-Selzle et al. [30] report that aerosol presence in the environment, regardless of the formation, can influence the longevity of disease occurrence due to its capacity to harbor pathogenic microorganisms [31]. In addition, aerosols' behavior and movement depend on meteorological conditions and the range of coastal dynamics such as wave currents, onshore wind direction, speed, etc. [32]. It is understood that coastal regions encompassing sea spray aerosols generated from sea waves, coastal wave currents, and surrounding water body mass have a bearing on the transmission of SARS-CoV-2 [33].

In spite of the studies confirming the role of climatic and environmental parameters on the COVID resurgence and high incidence rates, there are also other reasons that explain why there is a surge in cases during the outbreak of new variants. Early relaxation of community mitigation measures, easing travel bans, prevailing unvaccinated populations, adequate precautions, etc. were observed in a few countries [34]. Despite the fact that the majority of the studies about COVID transmission, incidence rate, and spread were examined relatively with climatic, meteorological, and environmental parameters, the association of coastal air mass flow and aerosol effect on the virus behavior is very scantily investigated.

From the above analysis, the study aims to focus specifically on coastal dynamics and its prospective scope on disease transmission across different countries and regions. The study's approach is to examine the specific role of aerosols that are normally driven by coastal air mass in coastal environments. These parameters will be analyzed, especially in different latitudinal zones, which might probably explain the influence of disease outbreaks or resurgence phenomena.

As a way forward, the following assumptions were considered to determine whether coastline dynamics have any substantial role in the COVID resurgence and resurfacing of infections regarding different latitudinal zones and thereby verify the significance between them to present the conclusions.

1-1- Theoretical Background

The need for the study was drawn considering the climate dynamics largely from the viewpoint of sea surface temperatures and turbulence fluctuations due to extreme weather events such as cyclones, typhoons, hurricanes, etc. occurring between the sea and landforms interface. Many empirical and review studies have been published by various researchers who studied the role of sea surface temperature on latent heat flux in regional and global contexts [14–16], while the factors determining the latent heat flux over water bodies were also extensively examined by Meng et al. [17]. Further Huang [19] explained the significance of ocean circulation in building differences in heat flow rates at different latitudinal ranges, in addition to similar studies published by Zhang & McPhaden [20] in the domain area, which formed the basis for our study concept. While there were no studies possibly established to understand the role of climate variables (latent heat) in different latitudinal zones, which might probably explain the influence on disease outbreaks. Therefore, to explore the principal role of climate variables in coronavirus disease incidence from the resurgence, the authors have intended to accomplish the objectives of the study by formulating the below prepositions to arrive at some conclusions from this research.

H_0: *Cases per million population reported in countries is a cause of latitude range.*

H_1: *Latent heat flux peak latitude range influences an increase in the incidence rate and cases observed in countries.*

H_2: *Coastal dynamics is a subjective factor affecting latent heat flux in different latitude range countries.*

1-2- Literature Review

The coronavirus disease was declared a pandemic due to its widespread transmission, spread, and resurgence that was felt across every nation. The pandemic paralyzed every walk of life, as it disrupted almost every sector, economy, human life, health, education, tourism, business, etc. [35]. From the directives issued by WHO, governments responded with different measures to prevent transmission and spread of the virus in order to contain the pandemic reaching dangerous levels. The reason for the virus to sustain for over more than 3 years in ambient environments is possible due to the adaptation of the virus through mutations. In addition, the presence of favourable conditions are very important aspects to investigate the agents of transmission and spread of the disease. This, therefore, has drawn the attention of many researchers to study the transmission and spread including the factors that sustain the virus in the ambient environments.

The disease is transmitted when virus-laden aerosol droplets are inhaled through the respiratory route from an infected person or the infected environment [36, 37]. Transmission can take place over short to long distances particularly in an indoor environment [38], while in an outdoor environment, many factors are known to facilitate the transmission, spread, and viability of the virus over longer periods. Cao et al. [39]; Guo et al. [40]; and Notari [41] studied the meteorological factors that influence the transmission of disease. Few studies exist explaining the relationship between ambient aerosol and SAR-CoV-2. Other studies on climatic factors indicate a positive correlation between temperature and incidence causing more deaths in US counties [42].

Bergero et al. [43] suggested that there could be a possible association between latent heat flux with Covid cases that might be explored to understand the incidence and resurgence phenomena in coastline habitats. While there is no sufficient data available on latent heat flux, analysis with the parameter were not conducted so far. However, other environmental parameters can be associated with latent heat flux which are studied in the case of dengue fever by different researchers. To examine the influence of latent heat flux from coastal environments on COVID incidence and resurgence in different latitudinal regions, data set on sea surface temperatures are not available, hence there are no studies existing pursued in this area, thereby the parameters conforming to coastal dynamics such as coastline length, latitudinal factors are not extensively explored by researchers. Hesham et al. [44] disclose COVID is predominantly an urban phenomenon showcasing a high possibility of transmission and incidence observed due to the dynamic nature of cities owing to high urban population density, air pollution, indoor environments, etc. Similar to the studies, the dominance of COVID cases over different geographical regions during winter and summer seasons indicates that humidity and temperature are two important factors determining the intensity of virus infections, and latent heat of evaporation from aerosol droplets with changing ambient weather also confirms the viability and transmission of the virus [45].

Hussein [46] investigation on the relationship between latent heat flux and sea surface temperature, reveals that latent heat flux and sea surface temperature over coastal waters have an association over limited temperature conditions, though the study confirms that both the parameters are governed by wind speed and humidity.

Moreover, there are no identified studies found linking the latent heat evaporation over water body mass, aerosol formation over sea coast habitats, and sea surface temperature on coastal aerosol parameters that possibly influence the disease transmission, incidence, and spread. While there are studies that exist considering a few climatic and meteorological parameters such as humidity, temperature differences, and aerosol from polluted environments, But the influence of coastline dynamics on latent heat flux and association with disease incidence and transmission remains unexplored in any context. Studies in this course are very essential to understand the role of coastal dynamics particularly from the view of latent heat of evaporation from coastal water body mass, and the significance they would have on disease incidence. Given pertinent gaps existing in this area, this study intends to examine the influence of latent heat flux on disease incidence rate in different latitudinal regions to ascertain the role of coastline parameters on COVID incidence.

2- Materials and Methods

The approach to examine the increasing incidence rate of coronavirus disease and the resurgence of infections, the significant climatic factor, study variables, quantitative data, and information required to present the findings are described in this section (Figure 1).

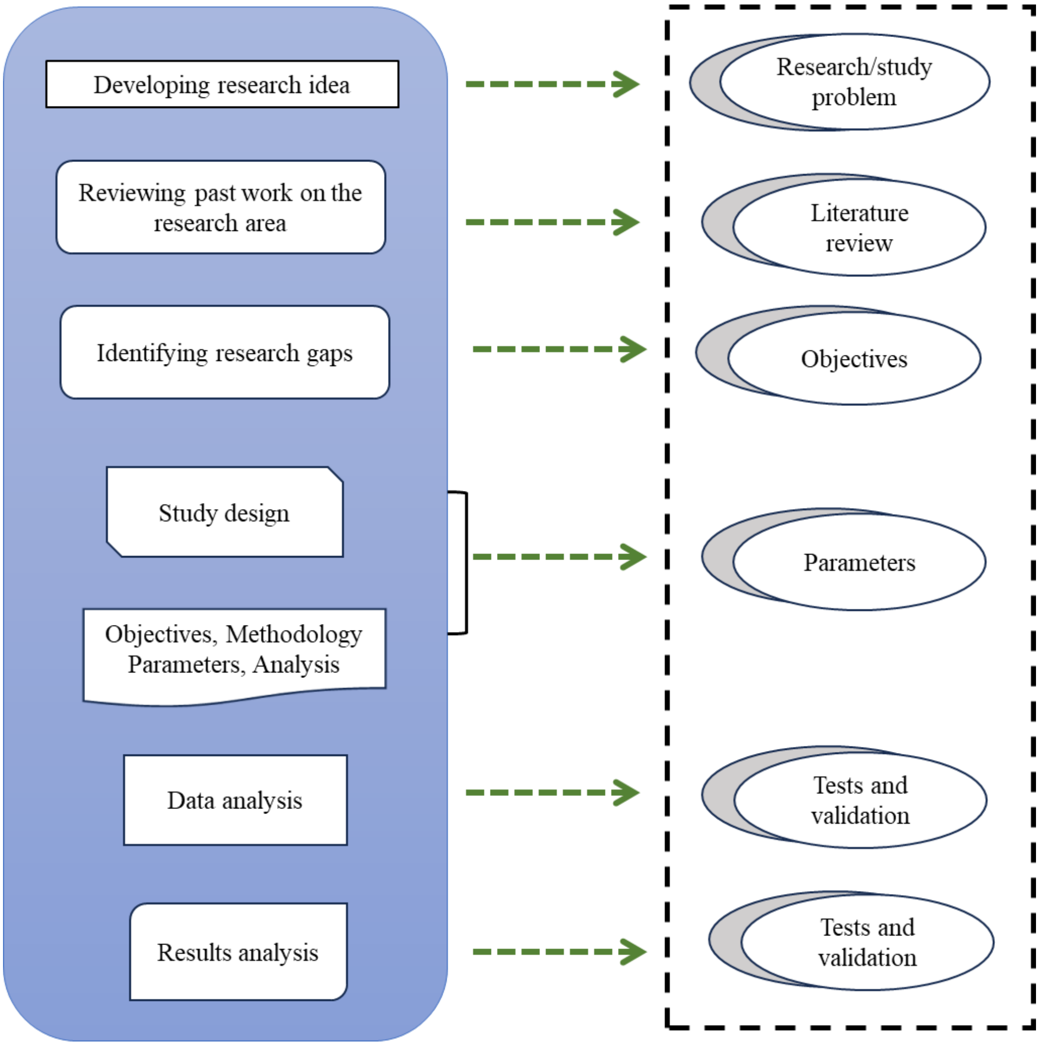

Figure 1. Process flow chart showing the study methodology

2-1- Data and Sources

The study focuses on data related to coastline length, latitudes, number of cases per million population, and population density from N=120 countries spanning 5 continental regions of the world. A total number of countries N =120 considered for the study are grouped into two datasets which are categorized in two criteria 1 & 2. The details of the countries studied under each criterion and the descriptive statistics related to the parameters of the study are presented in the results section. Cases per million population in both dataset countries reported until 20th January 2022 were considered. The information concerning the parameters was gathered [47-52]. Alternatively, relevant information needed for our study is also collated from analyzing scientific literature published by various researchers on the subject.

2-2- Data Analysis

The quantitative data for criteria 1 and 2 observations are statistically analyzed with simple linear regression analysis, multiple regression, and correlation analysis to estimate the degree of relationship and variables of prediction. Descriptive statistics on all the parameters of the study are performed and tabulated to understand the incidence rate trend in both criteria observations. Statistical analysis between the variables of the study is performed using SPSS ver.26 and NCSS statistical licensed software while the data tabulation is done using MS Excel 365 version.

3- Results and Discussion

3-1- General Interpretation

Coronavirus disease impacted every country across the globe in different phases which caused a steep rise in infection rate. The high incidence rates particularly observed in some countries are led by principal factors such as ceasing protection measures, mutations of the virus into new variants, and climatic and sociodemographic patterns. Among them, analysis of the influence of climatic factors especially, the significance of latent heat rate indicative of relative coastline length in determining the resurgence and rise in incidence rate are prominently explored in this study. To confirm an association between the parameters of the study, the chosen variables are examined in a total of 120 countries across 5 continents including the top 10 countries having the longest coastline lengths (refer to Table 1).

Table 1. Descriptive analysis of the parameters under study for the criteria 1 country

Latitude range °	Total countries (N)	Number countries	Cases/1M population			Coastline length (km)		
			Mean	SD	Range	Mean	SD	Range
35° to 40°	120	10	101430.6	83672.8	205887.0	6962.0	6766.7	19924.0
40° to 50°		32	146460.1	87363.9	385871.0	958.6	2000.9	7600.0
50° to 60°		12	174702.5	55856.1	151284.0	20798.2	57448.2	202080.0
25° to 35°		18	87658.4	73099.1	250354.0	2128.1	6929.6	29751.0
Below 25°		43	53585.5	51915.9	226782.0	4029.0	9730.9	54720.0

Observations about the variables in both data set countries are grouped according to the latitudinal ranges representing as control factor and cases reported per million population and coastline length as relative factors.

3-2- Descriptive Statistics

Descriptive analysis of the various parameters in the study for criteria 1 and 2 countries reveals a diverse course between the control factors and relative factors across the observations. Continental regions and countries considered under both categories for the study are presented in Tables 2 and 3. In criteria 1country, case per million population, and coastline length were examined in 5 different latitudinal ranges, and from the total of 120 countries considered, the least number of cases per million population were reported in countries that lie below 25° latitude, while the highest cases per million population are reportedly observed in countries lying between 50° to 60° latitude with least number of countries falling in this latitude range from the data group (Table 1). The mean values of cases per million population in the criteria 1 group were (99180.6 ± 80647.1), the mean latitudinal range (32.09 ± 16.35), and the mean coastline length (km) (5736.0 ± 20402 .1) obtained from the analysis (Figure 2).

Table 2. Criteria 1 study regions countries in each region considered for the analysis

Continental region	Countries
South America	USA, Canada, Mexico, Guatemala, Haiti, Cuba, Honduras, Nicaragua, El Salvador, Costa Rica, Panama, Jamaica, Trinidad and Tobago, Barbados.
North America	Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, French Guiana, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela.
Asia	Afghanistan, Armenia, Bahrain, Bangladesh, Bhutan, Brunei, Cambodia, China, Hong Kong, India, Indonesia, Iran, Iraq, Israel, Japan, Jordan, Kazakhstan, Kuwait, Kyrgyzstan, Laos, Lebanon, Macau, Malaysia, Maldives, Mongolia, Myanmar, Nepal, North Korea, Oman, Pakistan, Palestine, Philippines, Qatar, Saudi Arabia, Singapore, South Korea, Sri Lanka, Syria, Taiwan, Tajikistan, Thailand, Turkey, Turkmenistan, United Arab Emirates, Uzbekistan, Vietnam, Yemen, Azerbaijan, Georgia.
Europe	Russia, Turkey, Germany, United Kingdom, France, Italy, Spain, Ukraine, Poland, Romania, Netherlands, Belgium, Czech Republic, Greece, Portugal, Sweden, Hungary, Belarus, Austria, Switzerland, Serbia, Bulgaria, Denmark, Finland, Norway, Slovakia, Ireland, Croatia, Moldova, Bosnia and Herzegovina, Armenia, Albania, Lithuania, Slovenia, Latvia, Estonia, Cyprus, Luxembourg, Montenegro, Andorra, Monaco, Vatican City.
Oceania	Australia, New Zealand.

Table 3. Criteria 2 Study area countries having the top 10 longest coastline

Continental region	Country
North America	Canada, USA
Asia	Russia, Indonesia, Philippines, Japan, China
Europe	Norway
Oceania	Australia, New Zealand

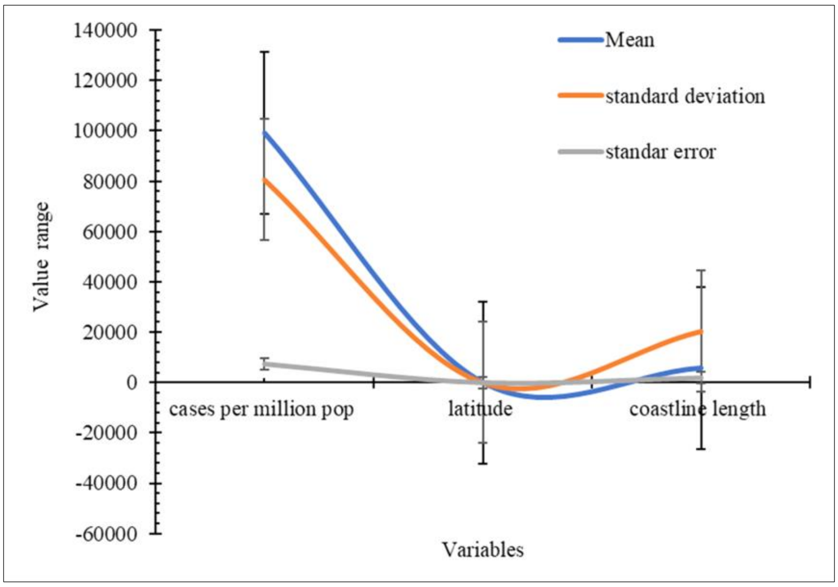

Figure 2. Mean values of variables observed in criteria 1 group countries

In addition, the countries in this latitude range also have the mean highest coastline length, whereas the least mean highest coastline length is observed in countries lying between 40˚ to 50˚ latitude. Analysis of the tabular data on criteria 1 country, discloses that the cases reported per million population is highest in countries that have the mean highest coastline length thus indicating an association between the rise in cases per population and coastline length which is a measure of latent heat flux can be established (Figure 3).

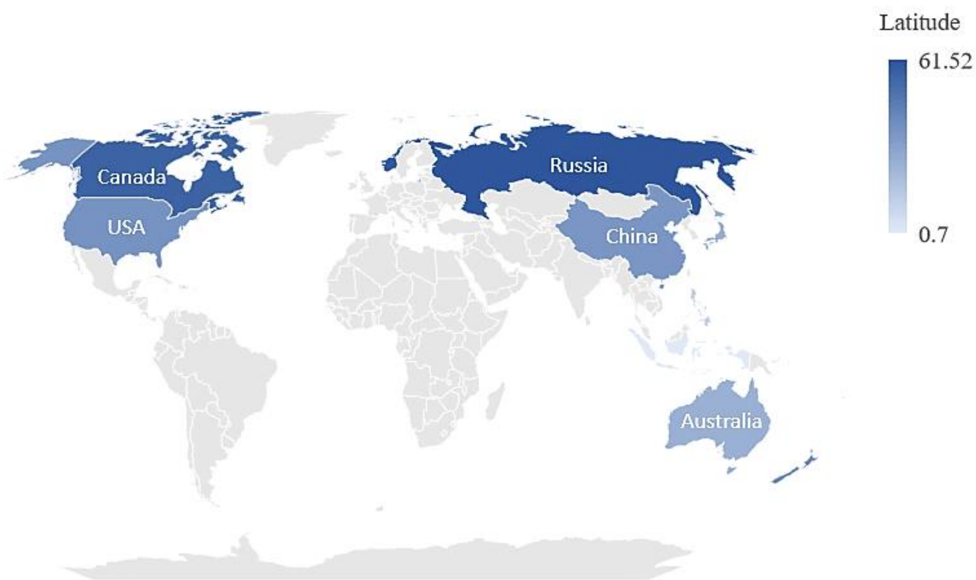

Figure 3. Map showing the latitudinal ranges of Criteria 1 country in the study

Further, studying the criteria 1 country, the majority of the countries have a coastline within 3000 km while the mean highest cases reported per million population is observed in countries which have a coastline range between 10000 to 20000 km, though the coastline length and cases per million population are not directly proportional to each other (Table 4).

Table 4. Criteria 1 country parameters under study categorized into different coastline range[1]

Coastline range (km)	Descriptive data	Count	Coastline length (km)	Cases/million population	Latitude °
0 to 3000	Mean	88	635.33	97358.24	31.53
	SD		820.92	83943.95	15.74
	Minimum		0.0	0.0	1.35
	Maximum		2800.0	385871.0	61.92
3000 to 6000	Mean	12	4164.90	124846.45	30.19
	SD		1017.79	69952.94	19.62
	Minimum		3148.00	20894.0	4.20
	Maximum		5835.00	225038.00	60.12
6000 to 10000	Mean	8	7750.71	107529.14	36.56
	SD		920.03	56688.19	11.02
	Minimum		6345.0	27053.00	20.59
	Maximum		9330.0	197885.00	56.26
10000 to 20000	Mean	5	15132.25	148910.75	41.84
	SD		2863.07	88655.05	7.89
	Minimum		12429.00	73.00	35.86
	Maximum		19924.00	225013.0	55.37
20000 above	Mean	7	69771.0	50466.8	36.3
	SD		60030.3	31794.3	24.2
	Minimum		29751.0	15119.0	0.70
	Maximum		202080.0	95399.0	61.5

[1] Some countries have not reported/disclosed COVID cases, hence no data exists with WHO

Countries having coastline length beyond 20000 km does not lead to a high incidence rate but the increase in cases tends to be more oriented towards latitudinal changes, specifically beyond 40˚ latitudes in criteria 1 country. An overall analysis of the observations on criteria 1 country reveals significant relation exists between the rise in the incidence rate and length of the coastline of countries, but how these two parameters influence each other is regulated by the latitudinal change (Figure 4).

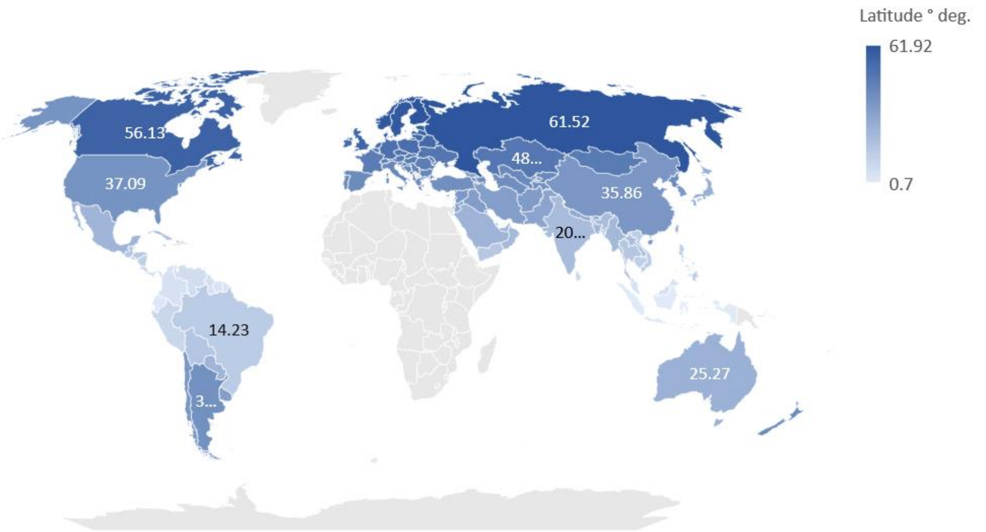

Figure 4. Map showing the latitudinal ranges of Criteria 1 country in the study

Examination of parameters understudy for criteria 2 countries presents observations differing from criteria 1 country. The cases per million population and coastline length show that the highest cases reported in this group seemingly are not from the countries that have the longest coastline length and vice versa, moreover, the increase in cases reported is not consistently observed with an increase in the coastline length, but there is considerable influence of latitudinal changes in ascertaining the incidence rate noted in these countries. Further, the mean highest cases per million population are reported in countries that are in between 26˚ to 40˚ latitude range where the mean coastline length is lowest among the criteria 1 country revealing that incidence rate increase in countries among the top 10 longest coastlines is because of their geographical presence in particular latitude ranges while the coastline length influence is relatively weak (Table 5).

Table 5. Descriptive analysis of the parameters under study for the criteria 2 countries

Total countries (N)	Cases/1M population			Latitude		
	Mean	SD	Range	Mean	SD	Range
10	56327.2	61093.0	202417.0	33.43	18.88	60.82

At this point, coastline length which is a measure of latent heat value (LHF) also corresponds to the evapotranspiration from the land surface therefore, the amount of landmass in terms of land area (km^2) which varies in different countries tends to cause fluctuations in heat exchanges between the land mass and surrounding coastal water mass resulting in a difference of latent heat generation. Atmospheric studies substantially prove that the latent heat values tend to peak at latitudes around 40˚ where COVID cases globally are found to be extreme at around 50˚ latitude, Large & Pond [15] from this analysis, hypothesis H1 is considerably justified based on descriptive study of the data from criteria 2 countries.

3-3- Statistical Analysis

Statistical analysis in criteria 1 country to determine the degree of relationship among the variables of the study was done using Pearson correlation and the associations are interpreted. The analysis indicates a moderate correlation exists between cases reported per million population $r = 0.425$, $p < 0.01$, $n = 120$ and latitude ranges thus denoting a signification relationship at $\alpha = 0.01$ level, while the association between the cases per million population and coastline length in km of the countries under criteria 1 reveals very weak to negligible negative relation $r = -0.072$, $p = 0.428$, $n = 120$ implying the cases per million population reported overtime is not significantly influenced with the coastal length (km) of countries in the group ($\alpha = 0.05$ level). Statistical analysis of countries in criteria 1 group using multiple regression analysis among the three variables cases reported per million population, latitude ranges, and coastline length (km) to determine the effect of independent variables on the outcome variable.

This analysis is done to verify whether coastline length a measure of latent heat flux is a subjective factor and whether latitude ranges are factors influencing the COVID incidence rate by increasing the cases per population in criteria 1 target countries. Results show the regressor variables statistically significantly predict the criterion variable $F(2,117) = 14.44$, $p < 0.01$, $R^2 = 0.198$ indicating that 19.8 % of the variability in cases reported per million population is targeted by latitude changes and coastline length of the countries (Figure 5).

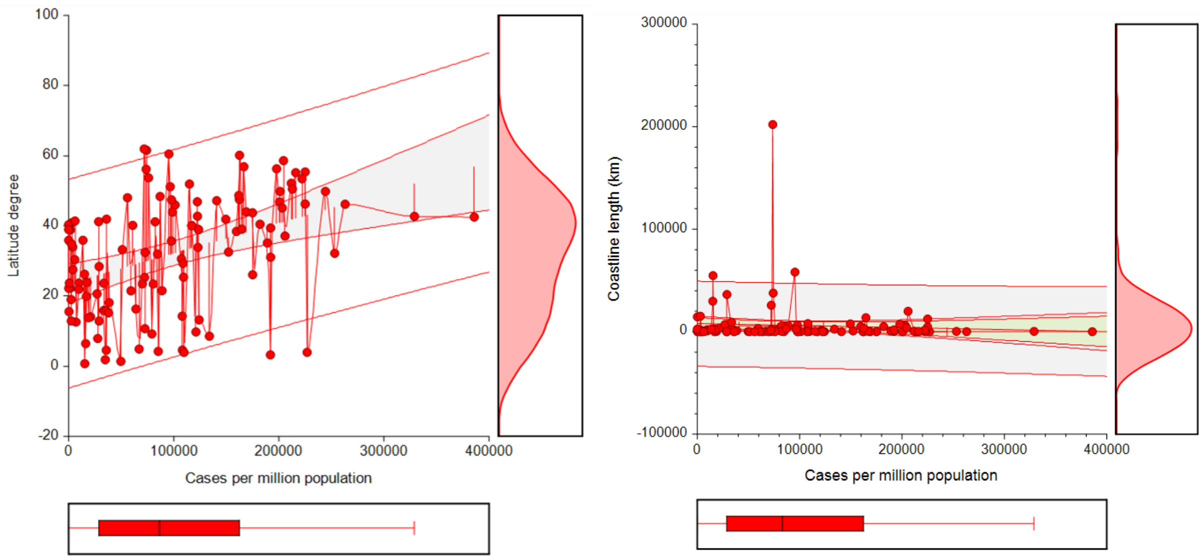

Figure 5. Linear regression scatter plot between cases per million population, latitude, and coastline length (km) in criteria 1 group countries

Among the two regressor variables, predictor latitude ($\beta = 0.443$, $t = 5.30$, $p < .01$) significantly predicts the cases per million population in the criteria 1 group countries at α .05 level while the predictor variable coastline length (km) ($\beta = -0.132$, $t = -1.57$, $p = 0.118$) does not significantly predict the outcome variable at $\alpha = 0.05$ level. Pearson correlation analysis of the top ten countries with the longest coastline length grouped in criteria 2 countries was performed among the variable's cases per million population, latitude, and coastline length to prove the degree of association and identify the predictor variables that majorly decide the outcome variable in the study group.

The analysis shows a weak positive association of cases per million population r = 0.356, p = 0.312, n = 10, with latitude implying no significant relation between them in countries having the longest coastline length, while the correlation analysis of cases per million population with coastline length shows almost no association r = 0.090, p = 0.804, n = 10 revealed no significant relationship exists between them in criteria 1 group countries. Multiple regression analysis among the variables shows the predictor variables latitude and coastline length statistically do not significantly predict the criterion variable *F* (2,7) = 0.514, p = 0.619, R2 = 0.128 denoting that 12.8 % of the variance in cases reported per million population in the criteria1 group countries is affected by latitude and coastline length. The individual predictor variables latitude (β = 0.367, t = 0.981, p = 0.359) and coastline length (β = -0.032, t = -0.084, p = 0.935) do not significantly predict the outcome variable in the criteria 1 group countries (Figure 6).

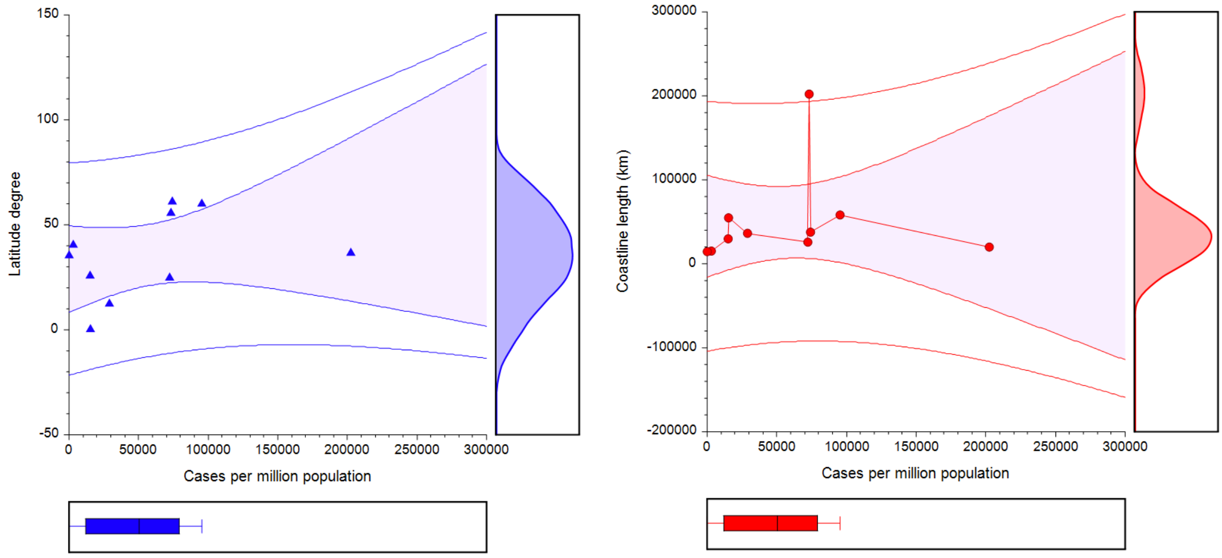

Figure 6. Linear regression scatter plot between cases per million population, latitude, and coastline length (km) in criteria 2 group countries

3-4- Data Analysis from Five Continental Regions

A descriptive analysis of variables was performed in the five different continental regions namely, South America, North America, Asia, Europe, and Oceania. The mean values of the variables across the five continental regions of criteria 1 calculated are presented in Table 6.

Table 6. Descriptive data analysis of variables of study in five continental regions of criteria 1 countries

Continental region	Descriptive data	Count	Cases/million population	Coastline length (km)	Latitude °
North America	Mean	14	70697.14	17611.43	19.65
	SD		58650.02	53367.4	12.75
	Minimum		2395	97	8.53
	Maximum		205887	202080	56.13
South America	Mean	13	99543.2	2418.3	15.02
	SD		55959.6	2613.0	13.20
	Minimum		16203	0	1.83
	Maximum		226901	7941	38.41
Asia	Mean	49	52820.2	3846.5	26.31
	SD		60607.4	10095.5	12.10
	Minimum		0	0	0.7
	Maximum		253151	54720	48.01
Europe	Mean	42	165579.1	4308.3	48.22
	SD		70460.37	10668.9	6.91
	Minimum		36070	0	35.12
	Maximum		385871	58133	61.92
Oceania	Mean	2	37653.5	20447	33.08
	SD		48960.78	7513.7	11.05
	Minimum		3033	15134	25.27
	Maximum		72274	25760	40.9

The highest mean cases were reported from the European region which also includes the UK, followed by South America, North America, Asia, and Oceania. Cross-examining mean values of variables from the tabular data reveals that the continental region with the highest recorded cases per million population has the lowest coastline length (km) while the continental regions having the highest coastline length have reported moderate cases per million population and a similar trend is observed across the five continental regions of the study. In addition, scatter plot diagrams to determine the relationship between cases and coastline length in each continental region reveals slight positive relationships among them in the case of North America and Oceania while in the rest of the regions, there is null relation observed between the two variables (Figure 7).

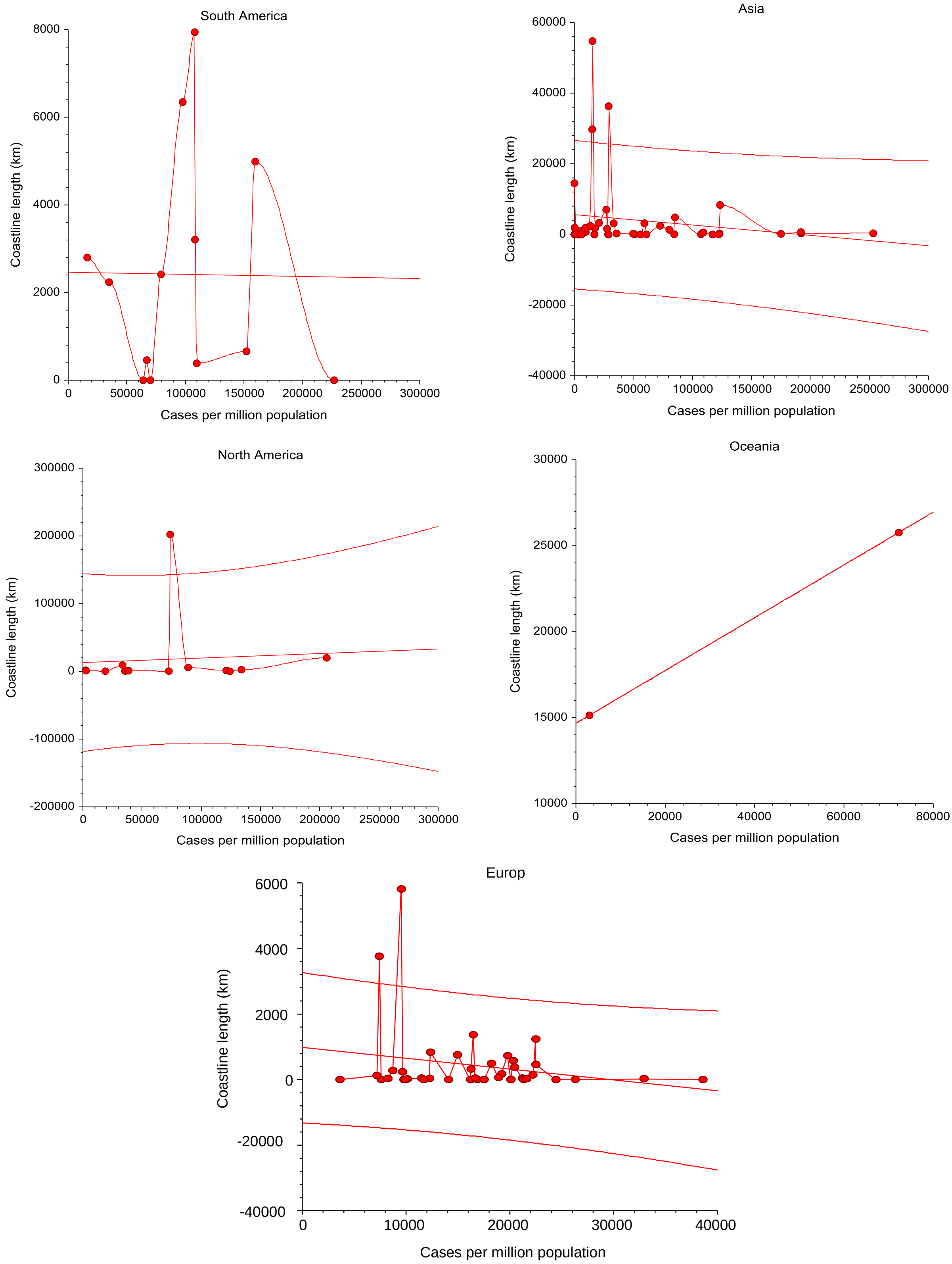

Figure 7. Scatter plot diagrams indicate the relation between cases per million population and coastline length in five continental regions

4- Discussion

SARS-CoV-2 is the strain of virus belonging to the group coronavirus that caused COVID, an infectious disease leading to severe respiratory illness among humans. The virus gets transmitted through airborne media, where human-to-human transmission happens through inhaling the infected aerosols or respiratory droplets either from an infected environment or an infected person. The transmission, spread, and viability of the SARS-CoV-2 are critical aspects that are important to explain the phenomena of disease incidence and resurgence observed in different regions. The etiology of COVID intensity due to the high incidence rate, and increase in cases can be elucidated from different perspectives to predict the pandemic growth. Scientific evidence shows climatic, environmental, and meteorological parameters along with socio-demographic patterns, which are investigated extensively to predict the disease transmission, spread, and incidence phenomena in different countries. Factors like temperature, humidity, precipitation, solar radiation, topography, latitude, aerosols, air pollutants, wind speed, ventilation, etc. are parameters that change over time and space and each of these parameters interrelate and interact with each other. Specific climatic, environmental, and meteorological parameters were examined by various researchers in the past to enumerate the degree of influence on disease transmission, spread, and viability in concurrence with the socio-demographic pattern. In this study, we intend to specifically analyze the role of latent heat flux transforming latent heat energy from ocean circulation on the disease incidence and resurgence of cases in different geographic regions. As there are no significant studies done on this interpretation, our aim of this study is to verify the association of climatic factors such as latent heat energy would have in influencing the increase in cases with latitude and determine whether coastline length subjectively affects the latent heat energy production from the aerosols in different countries.

Latent heat flux is an important climatic parameter concerning atmosphere-ocean interactions, mostly impacted by changing sea surface temperatures (SST) due to ocean warming. Numerous studies also indicate a positive or negative correlation between SST and latent heat flux in different intensities based on the latitudinal position of each country, which reveals varying degrees of disease incidence rate and resurgence. In contrast, as SST data are not currently being published globally to evaluate the latent heat energy from atmosphere-ocean interactions, a precise mechanism to assess the impact of latent heat energy on disease incidence at different latitudes leads to constraints towards such research. Therefore the nearest parameter to understand the implications of atmospheric ocean interactions would be to consider the coastline length, as a reasonable factor for latent heat flux. There are few studies found close to our present study objective which reveals coastal habitats harbor aerosol production leading to contamination of the population with airborne pathogens [33]. Further, the reports of COVID were also linked to countries in the equatorial and poles, while the countries in such distribution were not analyzed about the coastline which is a measure of latent heat energy [53]. Our study considers the extent of coastline length, and water body mass circulation resulting in aerosol production which can increase the airborne density of pathogens.

Analyzing the COVID incidence from our observation from the tropics to the poles, the second wave outbreak was reported from January to April, which coincided with the escalation of more fatalities reported in Europe during the same period. COVID fatality per million cases was observed to be varying with latitude, with more persons on average succumbing to severe infections at high latitudes compared to regions close to the tropics. Particularly the pandemic was

Resurgence observed in many countries where there were a rise and fall in infection cases over the last two years (2021-2022). The trend was mostly observed during the outbreak of new variants from mutations. Contrary to the understanding, the resurgence of the disease particularly in some geographic regions, is probably attributed to the climatic variables indicating the role of specific environmental factors that favor the spread, viability, and infection. In our study context parameters such as atmospheric latent heat flux, solar radiation, and exposure rate from the indoor and outdoor environment, urban pollution affects the viability, and survival, shows the potential to spread successfully through the airborne media. Besides, the climate variables coastline length signifying latent heat flux of region substantially influences incidence rate leading to rising of more infection cases where the highest cases are reported around maximum coastline length range correspondingly found in peak latitude range, thus implying that changes in atmospheric heat fluxes will result in fluctuations in incidence rate [16]. In conjunction with the above observations, the incidence and raise in cases of COVID in different regions have some degree of association with temperature, indicating the fluctuations in this parameter are bound to influence the pattern of pandemic flow. A similar tendency of association was also reported with latitude from the epidemiological studies stated by Burra et al. [54].

Our analysis closely indicates that latent heat flux peaks at latitudes 40˚ where the peak fatalities of disease are observed at 50˚ latitude with the lowest fatalities occurring close to 15˚ latitude, revealing that in a 10˚ latitude margin, the disease incidence rate is likely to rise and fall deeply in the order of 6 times, these observations resolve the preposition H1 that latent heat flux as a measure of coastline length influence the incidence rates, but this scenario may mostly prevail in countries located in peak latitudes. On the other hand, the resurgence of disease cases cannot be ascertained fully on the climate variables, while demographic and non-climatic factors are known to impact the pandemic outcomes to a considerable extent according to reports [55, 56]. This argument is observed from our study in a few continental regions where the incidence rate through a rise in cases has no definite association with the extent of coastline and subsequent latent heat flux. But in theory, the resurgence of cases from COVID is either due to the emergence of new variants or possibly a rise in infection rates thereby is also largely due to demographic factors such as poor socioeconomic factors, ease of restrictions in some countries, population structure and density patterns, health care facilities, etc. which explains why the infection rates are differently observed in countries in the same geographic region and latitude zone, despite variance in coastal volume and atmospheric heat flux [57-59].

Conversely, latent heat flux over a region tends to influence the disease infections rates, deaths, and spread as more people on average succumb to infections at high latitudes compared to regions close to the equator, thereby which confirms our study proposition that increase in cases reported are affected by latitudinal ranges of countries, in accordance to the observations made by Chen et al. [60]. Further, mild links can be established to confirm the role of atmospheric latent heat flux on the stability and spread of infections in countries surrounded by water bodies as results from the study indicate in countries having long coastlines tend to show a decrease in cases and infection rates which is consistent to our preposition H2 that coastline length affects the latent heat paradigm of every county that varies with latitudinal ranges.

The rise in cases and resurgence of infections across many countries is also affected by climate variables such as solar radiation intensity, temperature differences, humidity, water evaporation from surrounding water bodies leading to heat energy balance, latitudes of countries, etc. all were examined to have some degree of association on the spread, transmission, stability, and viability of the virus. Moreover, our results are consistent with the three prepositions specified in the study and agree with the previous studies, confirming that the climate variables such as latitude, and atmospheric latent heat flux corresponding to the extent of coastline length show a considerable degree of association with the resurgence of COVID. Accordingly, extensive analysis from the previous study also shows complex correlation dynamics between atmospheric latent heat flux with the fatalities from COVID with death counts peaking in the poleward direction and decreased cases at minimal flux values which provide sufficient grounds for validating the three prepositions of the study

Besides, sufficient previous studies have been conducted proving the role of heat and UV radiation at different latitudes in causing the spread of SARS-CoV-2. Buonanno et al. [61]; Menebo [62]; Chin & Poon [63]; and Sonja [64], where the intensity of resurgence is felt to varying extents in different countries coincidental with the propagation of COVID waves from the tropics to the poles. For this reason, the synchronous COVID fatalities among countries in any given region of the world indicate the regional-wide influence that can be least fully explained from localized demographic data. Following that, the incidence rate and resurgence of cases in aerosolized environments from polluted cities also affect turbulence flux, showing the greatest impact on sensible heat flux and latent heat flux, causing the virus to remain stable and remain infectious for longer periods under a lower flux range [64].

Regarding the environmental parameters, they are understated, which is also apparent from our review paper last year. In general, many papers have (understandably) focused on indoor living conditions and the rate of viability of the virus against temperature and relative humidity. Relative humidity changes with temperature as well as with moisture content. This obscures the latent heat dependence of the virus. A better reference for virus viability is the dew point temperature, which, for a given ambient condition, is dependent on moisture content alone. A good example of how atmospheric conditions can turn around the impetus of COVID is that of a recent outbreak in India in May 2021. The outbreak, which was intense and rapid, was quickly brought under control within 2–3 weeks of an otherwise chaotic and desperate situation. This is largely a result of the approaching south-west monsoon front, which is substantially heating the atmosphere through the release of transported latent heat. Unfortunately, throughout last year, the WHO was not convinced that Cov-2 was airborne. As a result of this, until today, many administrations do not emphasize and, at times, do not even mention the importance of ventilation. The above results, alongside, our earlier results on City Life (graph below), show that ventilation is paramount in reducing infection rates. The results are consistent with previously reported high rates of infections that were observed during the earliest days of the pandemic.

Further, more detailed studies are required to precisely understand the determinant factors of resurgence and incidence phenomena, particularly among countries in coastal habitats, and also how the COVID cases transit from the tropics to the poles. In addition, emphasis on latent heat flux from sea surface temperature needs a thorough analysis to comprehend the role the climatic factors have in the transmission and spread of COVID, while that information would be useful to predict the disease progress and take preventive measures to overcome future pandemics.

5- Conclusion

The study examines the role of climate variables impacting in the rising incidence rate and understands the implications of the global resurgence of the pandemic. The significance of different climatic factors, environmental conditions, and weather conditions on virus spread, transmission, and viability is widely studied in different geographical contexts. Environmental parameters like temperature, relative humidity, precipitation, wind speed, air pollutants, aerosols, etc. are some factors known to play a significant role in the sustenance of SARS-CoV-2, leading to transmission and spread in the environment. Among these are demographic factors, because concern along with population migration is known to considerably affect the resurgence in certain situations. It is interesting to note that the implications of the incidence rate are not caused by a single factor but by a combination of factors contributed together, either involving environmental, climatic, and or demographic, as evidenced by various studies.

Apart from this, our study indicates that the combined role of latitude and coastline length in countries signifying latent heat flux can explain the increase in the incidence rate and resurgence in cases. Besides, the outcomes of our analysis also sufficiently fulfill the prepositions of our study, indicating that the rise in cases observed in the criteria country groups is caused by latent heat flux in conjunction with the coastline length at peak latitude ranges.

However, such a trend is not distinctly observed across all geographic continents that are examined, as latent heat flux shows varying energy balance from the tropics towards poles from studies proving the positive association of pole-ward latent heat flux with degree latitude and death counts. Likewise, coastline length and death count tend to show an association with the time of virus prevalence in the environment, as observed in the context of GCC countries. In the end, the analysis categorically states that the resurgence observed globally from the increase in the incidence rate and infections is also relatively due to the influence of climatic variables, among the other factors that are known to show the collective effect of disease transmission and spread of infection.

6- Declarations

6-1- Author Contributions

Conceptualization, H.M. and K.A.; methodology, H.J.; software, H.J.; formal analysis, H.M., K.A., and H.J.; writing—original draft preparation, H.J.; writing—review and editing, H.M. and K.A. All authors have read and agreed to the published version of the manuscript.

6-2- Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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6-5- Institutional Review Board Statement

Not applicable.

6-6- Informed Consent Statement

Not applicable.

6-7- Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

7- References

[1] WHO. (2023). WHO coronavirus dashboard. World Health Organization (WHO), Geneva, Switzerland. Available online: https://covid19.who.int/ (accessed on May 2023).

[2] Bollinger, R., & Ray, S. (2001). COVID variants: what you should know. Health, John Hopkins Medicine. The Johns Hopkins University, Baltimore, United States. Available online: https://www.hopkinsmedicine.org/health/conditions-and-diseases/coronavirus/a-new-strain-of-coronavirus-what-you-should-know (accessed on May 2023).

[3] Alam, Md. S., & Sultana, R. (2021). Influences of climatic and non-climatic factors on COVID-19 outbreak: A review of existing literature. Environmental Challenges, 5, 100255. doi:10.1016/j.envc.2021.100255.

[4] Xie, J., & Zhu, Y. (2020). Association between ambient temperature and COVID-19 infection in 122 cities from China. Science of the Total Environment, 724, 724. doi:10.1016/j.scitotenv.2020.138201.

[5] Mecenas, P., Bastos, R. T. da R. M., Vallinoto, A. C. R., & Normando, D. (2020). Effects of temperature and humidity on the spread of COVID-19: A systematic review. PLOS ONE, 15(9), e0238339. doi:10.1371/journal.pone.0238339.

[6] Rendana, M. (2020). Impact of the wind conditions on COVID-19 pandemic: A new insight for direction of the spread of the virus. Urban Climate, 34, 100680. doi:10.1016/j.uclim.2020.100680.

[7] Bilal, Bashir, M. F., Komal, B., Benghoul, M., Bashir, M. A., & Tan, D. (2021). Nexus between the covid-19 dynamics and environmental pollution indicators in South America. Risk Management and Healthcare Policy, 14, 67–74. doi:10.2147/RMHP.S290153.

[8] Contini, D., & Costabile, F. (2020). Does air pollution influence COVID-19 outbreaks? Atmosphere, 11(4), 377. doi:10.3390/ATMOS11040377.

[9] Ehsanifar, M. (2021). Airborne aerosols particles and COVID-19 transition. Environmental Research, 200. doi:10.1016/j.envres.2021.111752.

[10] Zhao, Y., Richardson, B., Takle, E., Chai, L., Schmitt, D., & Xin, H. (2019). Airborne transmission may have played a role in the spread of 2015 highly pathogenic avian influenza outbreaks in the United States. Scientific Reports, 9(1), 11755. doi:10.1038/s41598-019-47788-z.

[11] Nath, D., Sasikumar, K., Nath, R., & Chen, W. (2021). Factors Affecting COVID-19 Outbreaks across the Globe: Role of Extreme Climate Change. Sustainability, 13(6), 3029. doi:10.3390/su13063029.

[12] World Health Organization WHO). (2020). Coronavirus disease (COVID-19): Climate change. World Health Organization (WHO), Geneva, Switzerland. Available online: https://www.who.int/news-room/questions-and-answers/item/coronavirus-disease-covid-19-climate-change (accessed on September 2023).

[13] Amnuaylojaroen, T., & Parasin, N. (2021). The Association between COVID-19, Air Pollution, and Climate Change. Frontiers in Public Health, 9, 62499. doi:10.3389/fpubh.2021.662499.

[14] Kumar, P.B., Cronin, M. F., Joseph, S., Ravichandran, M., & Sureshkumar, N. (2017). Latent heat flux sensitivity to sea surface temperature: Regional perspectives. Journal of Climate, 30(1), 129–143. doi:10.1175/JCLI-D-16-0285.1.

[15] Large, W. G., & Pond, S. (1982). Sensible and Latent Heat Flux Measurements over the Ocean. Journal of Physical Oceanography, 12(5), 464–482. doi:10.1175/1520-0485(1982)012<0464:salhfm>2.0.co;2.

[16] Wu, R., Kirtman, B. P., & Pegion, K. (2007). Surface latent heat flux and its relationship with sea surface temperature in the National Centers for Environmental Prediction Climate Forecast System simulations and retrospective forecasts. Geophysical Research Letters, 34(17). doi:10.1029/2007GL030751.

[17] Meng, X., Liu, H., Du, Q., Liu, Y., & Xu, L. (2020). Factors controlling the latent and sensible heat fluxes over Erhai Lake under different atmospheric surface layer stability conditions. Atmospheric and Oceanic Science Letters, 13(5), 400–406. doi:10.1080/16742834.2020.1769450.

[18] Zhao, L., Qi, Y., Luzzatto-Fegiz, P., Cui, Y., & Zhu, Y. (2020). COVID-19: Effects of Environmental Conditions on the Propagation of Respiratory Droplets. Nano Letters, 20(10), 7744–7750. doi:10.1021/acs.nanolett.0c03331.

[19] Huang, R. X. (2013). Ocean, Energy Flows in. Reference Module in Earth Systems and Environmental Sciences. Elsevier, Amsterdam, Netherlands, doi:10.1016/b978-0-12-409548-9.01198-2.

[20] Zhang, G. J., & Mcphaden, M. J. (1995). The Relationship between Sea Surface Temperature and Latent Heat Flux in the Equatorial Pacific. Journal of Climate, 8(3), 589–605. doi:10.1175/1520-0442(1995)008<0589:trbsst>2.0.co;2.

[21] Ovadnevaite, J., Manders, A., De Leeuw, G., Ceburnis, D., Monahan, C., Partanen, A. I., Korhonen, H., & O'Dowd, C. D. (2014). A sea spray aerosol flux parameterization encapsulating wave state. Atmospheric Chemistry and Physics, 14(4), 1837–1852. doi:10.5194/acp-14-1837-2014.

[22] Dowd, C. D. O. (2001). Biogenic coastal aerosol production and its influence on aerosol radiative properties. Journal of Geophysical Research: Atmospheres, 106(2), 1545–1549. doi:10.1029/2000jd900423.

[23] Tang, J. W., Li, Y., Eames, I., Chan, P. K. S., & Ridgway, G. L. (2006). Factors involved in the aerosol transmission of infection and control of ventilation in healthcare premises. Journal of Hospital Infection, 64(2), 100–114. doi:10.1016/j.jhin.2006.05.022.

[24] Wong, T. W., Lee, C. K., Tam, W., Lau, J. T. F., Yu, T. S., Lui, S. F., Chan, P. K. S., Li, Y., Bresee, J. S., Sung, J. J. Y., & Parashar, U. D. (2004). Cluster of SARS among Medical Students Exposed to Single Patient, Hong Kong. Emerging Infectious Diseases, 10(2), 269–276. doi:10.3201/eid1002.030452.

[25] Yu, I. T. S., Wong, T. W., Chiu, Y. L., Lee, N., & Li, Y. (2005). Temporal-Spatial Analysis of Severe Acute Respiratory Syndrome among: Hospital Inpatients. Clinical Infectious Diseases, 40(9), 1237–1243. doi:10.1086/428735.

[26] Li, Y., Huang, X., Yu, I. T. S., Wong, T. W., & Qian, H. (2005). Role of air distribution in SARS transmission during the largest nosocomial outbreak in Hong Kong. Indoor Air, 15(2), 83–95. doi:10.1111/j.1600-0668.2004.00317.x.

[27] Booth, T. F., Kournikakis, B., Bastien, N., Ho, J., Kobasa, D., Stadnyk, L., Li, Y., Spence, M., Paton, S., Henry, B., Mederski, B., White, D., Low, D. E., McGeer, A., Simor, A., Vearncombe, M., Downey, J., Jamieson, F. B., Tang, P., & Plummer, F. (2005). Detection of airborne severe acute respiratory syndrome (SARS) coronavirus and environmental contamination in SARS outbreak units. Journal of Infectious Diseases, 191(9), 1472–1477. doi:10.1086/429634.

[28] Xiao, W. J., Wang, M. L., Wei, W., Wang, J., Zhao, J. J., Yi, B., & Li, J. S. (2004). Detection of SARS-CoV and RNA on aerosol samples from SARS-patients admitted to hospital. Zhonghua Liu Xing Bing Xue Za Zhi, 25(10), 882-885.

[29] Gholipour, S., Mohammadi, F., Nikaeen, M., Shamsizadeh, Z., Khazeni, A., Sahbaei, Z., Mousavi, S. M., Ghobadian, M., & Mirhendi, H. (2021). COVID-19 infection risk from exposure to aerosols of wastewater treatment plants. Chemosphere, 273, 129701. doi:10.1016/j.chemosphere.2021.129701.

[30] Reinmuth-Selzle, K., Kampf, C. J., Lucas, K., Lang-Yona, N., Fröhlich-Nowoisky, J., Shiraiwa, M., Lakey, P. S. J., Lai, S., Liu, F., Kunert, A. T., Ziegler, K., Shen, F., Sgarbanti, R., Weber, B., Bellinghausen, I., Saloga, J., Weller, M. G., Duschl, A., Schuppan, D., & Pöschl, U. (2017). Air Pollution and Climate Change Effects on Allergies in the Anthropocene: Abundance, Interaction, and Modification of Allergens and Adjuvants. Environmental Science and Technology, 51(8), 4119–4141. doi:10.1021/acs.est.6b04908.

[31] Kitajima, M., Ahmed, W., Bibby, K., Carducci, A., Gerba, C. P., Hamilton, K. A., Haramoto, E., & Rose, J. B. (2020). SARS-CoV-2 in wastewater: State of the knowledge and research needs. Science of the Total Environment, 739, 139076. doi:10.1016/j.scitotenv.2020.139076.

[32] Fitzgerald, J. W. (1991). Marine aerosols: A review. Atmospheric Environment. Part A. General Topics, 25(3–4), 533–545. doi:10.1016/0960-1686(91)90050-h.

[33] Piazzola, J., Bruch, W., Desnues, C., Parent, P., Yohia, C., & Canepa, E. (2021). Influence of meteorological conditions and aerosol properties on the covid-19 contamination of the population in coastal and continental areas in France: study of offshore and onshore winds. Atmosphere, 12(4), 523. doi:10.3390/atmos12040523.

[34] Hatef, E., Kitchen, C., Chang, H. Y., Kharrazi, H., Tang, W., & Weiner, J. P. (2021). Early relaxation of community mitigation policies and risk of COVID-19 resurgence in the United States. Preventive Medicine, 145, 106435. doi:10.1016/j.ypmed.2021.106435.

[35] Khan, S., Zayed, N. M., Darwish, S., Nitsenko, V., Islam, K. M. A., Hassan, Md. A., & Dubrova, O. (2022). Pre and Present COVID-19 Situation: A Framework of Educational Transformation in South Asia Region. Emerging Science Journal, 7, 81–94. doi:10.28991/esj-2023-sper-06.

[36] Wang, C. C., Prather, K. A., Sznitman, J., Jimenez, J. L., Lakdawala, S. S., Tufekci, Z., & Marr, L. C. (2021). Airborne transmission of respiratory viruses. Science, 373(6558), 1-13. doi:10.1126/science.abd9149.

[37] Greenhalgh, T., Jimenez, J. L., Prather, K. A., Tufekci, Z., Fisman, D., & Schooley, R. (2021). Ten scientific reasons in support of airborne transmission of SARS-CoV-2. The Lancet, 397(10285), 1603–1605. doi:10.1016/S0140-6736(21)00869-2.

[38] Miller, S. L., Nazaroff, W. W., Jimenez, J. L., Boerstra, A., Buonanno, G., Dancer, S. J., Kurnitski, J., Marr, L. C., Morawska, L., & Noakes, C. (2021). Transmission of SARS-CoV-2 by inhalation of respiratory aerosol in the Skagit Valley Chorale superspreading event. Indoor Air, 31(2), 314–323. doi:10.1111/ina.12751.

[39] Cao, Y., Shao, L., Jones, T., Oliveira, M. L. S., Ge, S., Feng, X., Silva, L. F. O., & BéruBé, K. (2021). Multiple relationships between aerosol and COVID-19: A framework for global studies. Gondwana Research, 93, 243–251. doi:10.1016/j.gr.2021.02.002.

[40] Guo, C., Bo, Y., Lin, C., Li, H. B., Zeng, Y., Zhang, Y., Hossain, M. S., Chan, J. W. M., Yeung, D. W., Kwok, K., Wong, S. Y. S., Lau, A. K. H., & Lao, X. Q. (2021). Meteorological factors and COVID-19 incidence in 190 countries: An observational study. Science of the Total Environment, 757, 143783. doi:10.1016/j.scitotenv.2020.143783.

[41] Notari, A. (2021). Temperature dependence of COVID-19 transmission. Science of the Total Environment, 763, 144390. doi:10.1016/j.scitotenv.2020.144390.

[42] Chu, B., Chen, R., Liu, Q., & Wang, H. (2023). Effects of High Temperature on COVID-19 Deaths in U.S. Counties. GeoHealth, 7(3), 2022 000705. doi:10.1029/2022GH000705.

[43] Bergero, P., Schaposnik, L. P., & Wang, G. (2023). Correlations between COVID-19 and dengue obtained via the study of South America, Africa and Southeast Asia during the 2020s. Scientific Reports, 13(1), 1525. doi:10.1038/s41598-023-27983-9.

[44] Magd, H., Asmi, K., & Henry, K. (2020). COVID-19 Influencing Factors on Transmission and Incidence Rates-Validation Analysis. Journal of Biomedical Research & Environmental Sciences, 1(7), 277–291. doi:10.37871/jbres1155.

[45] Dbouk, T., & Drikakis, D. (2020). Weather impact on airborne coronavirus survival. Physics of Fluids, 32(9), 093312. doi:10.1063/5.0024272.

[46] Hussein, M. M. A. (2022). Relationship between Latent Heat Flux and Sea Surface Temperature in Alexandria Eastern Harbor, Egypt. Turkish Journal of Fisheries and Aquatic Sciences, 22(6), 1-12. doi:10.4194/TRJFAS20642.

[47] Worldometer website. (2023). Worldometer: Real-Time World Statistics. Coronavirus Updates. Available online: https://www.worldometers.info/ (accessed on May 2023).

[48] World Population Review. (2023). Continent and regional population. World Population Review, Lancaster, United States. Available online: https://worldpopulationreview.com/continents (accessed on May 2023).

[49] World Atlas. (2023). Continents of the world. WorldAtlas, Saint-Laurent. Available online: https://www.worldatlas.com/ (accessed on May 2023).

[50] LatLong (2022). Latitude and Longitude. 2012-2022, Latitude and longitude finder. Available online: www.LatLong.net (accessed on May 2023).

[51] Burke, L., Kura, Y., Kassem, K., Revenga, C., Spalding, M., McAllister, D. (2001). Pilot Analysis of Global Ecosystems: Coastal Ecosystems; World Recourses Institute, Washington, United States.

[52] LePan, N., Routley, N., & Schell, S. (2020). Visualizing the history of pandemic. Visual Capitalist. Available online: https://www.visualcapitalist.com/history-of-pandemics-deadliest/ (accessed on May 2023).

[53] Nandin de Carvalho, H. (2022). Latitude impact on pandemic Sars-Cov-2 2020 outbreaks and possible utility of UV indexes in predictions of regional daily infections and deaths. Journal of Photochemistry and Photobiology, 10, 100108. doi:10.1016/j.jpap.2022.100108.

[54] Burra, P., Soto-Díaz, K., Chalen, I., Gonzalez-Ricon, R. J., Istanto, D., & Caetano-Anollés, G. (2021). Temperature and Latitude Correlate with SARS-CoV-2 Epidemiological Variables but not with Genomic Change Worldwide. Evolutionary Bioinformatics, 17. doi:10.1177/1176934321989695.

[55] Bashir, M. F., Ma, B., & Shahzad, L. (2020). A brief review of socio-economic and environmental impact of Covid-19. Air Quality, Atmosphere & Health, 13(12), 1403–1409. doi:10.1007/s11869-020-00894-8.

[56] Ahmad, S., Shoaib, A., Ali, M. S., Alam, M. S., Alam, N., Ali, M., Mujtaba, M. A., Ahmad, A., Ansari, M. S., & Ali, M. D. (2021). Epidemiology, risk, myths, pharmacotherapeutic management and socio-economic burden due to novel covid-19: A recent update. Research Journal of Pharmacy and Technology, 14(4), 2308–2315. doi:10.52711/0974-360X.2021.00408.

[57] Singh, R. P., & Chauhan, A. (2020). Impact of lockdown on air quality in India during COVID-19 pandemic. Air Quality, Atmosphere & Health, 13(8), 921–928. doi:10.1007/s11869-020-00863-1.

[58] Seale, H., Dyer, C. E. F., Abdi, I., Rahman, K. M., Sun, Y., Qureshi, M. O., Dowell-Day, A., Sward, J., & Islam, M. S. (2020). Improving the impact of non-pharmaceutical interventions during COVID-19: examining the factors that influence engagement and the impact on individuals. BMC Infectious Diseases, 20(1), 607. doi:10.1186/s12879-020-05340-9.

[59] Hawkins, R. B., Charles, E. J., & Mehaffey, J. H. (2020). Socio-economic status and COVID-19–related cases and fatalities. Public Health, 189, 129–134. doi:10.1016/j.puhe.2020.09.016.

[60] Chen, S., Prettner, K., Kuhn, M., Geldsetzer, P., Wang, C., Bärnighausen, T., & Bloom, D. E. (2021). Climate and the spread of COVID-19. Scientific Reports, 11(1), 9042. doi:10.1038/s41598-021-87692-z.

[61] Buonanno, M., Welch, D., Shuryak, I., & Brenner, D. J. (2020). Far-UVC light (222 nm) efficiently and safely inactivates airborne human coronaviruses. Scientific Reports, 10(1), 1–8. doi:10.1038/s41598-020-67211-2.

[62] Menebo, M. M. (2020). Temperature and precipitation associate with Covid-19 new daily cases: A correlation study between weather and Covid-19 pandemic in Oslo, Norway. Science of the Total Environment, 737, 139659. doi:10.1016/j.scitotenv.2020.139659.

[63] Chin, A. W. H., Chu, J. T. S., Perera, M. R. A., Hui, K. P. Y., Yen, H. L., Chan, M. C. W., Peiris, M., & Poon, L. L. M. (2020). Stability of SARS-CoV-2 in different environmental conditions. The Lancet Microbe, 1(1), e10. doi:10.1016/S2666-5247(20)30003-3.

[64] Sonja, M. (2017). The impact of aerosols on the sensible and latent heat fluxes in Beijing. Master Thesis, University of Helsinki, Helsinki, Finland.