

Table 1. Included Primary Studies: Study characteristics and summary findings

Study ID	Method	Population	Study dates	Exposures & comparison/control, where reported	Outcomes investigated	Study findings summary statement
Table 1a. Exposure: altitude						
Arias-Reyes 2021	retrospective study using international surveillance data, including modelling to estimate transmission rates and case fatality rates	23 countries on the American continent	Feb to May 2020	altitude	incidence of COVID-19	incidence decreased significantly starting at 1,000 m above sea level; estimated transmission rates lower in highlands than lowlands; estimated case fatality lower in highlands than lowlands
Campos 2021	observational study using province-level data	23 provinces of Ecuador (all except Galapagos Islands)	February to August 2020	altitude	incidence, mortality and case-fatality rate of COVID-19	altitude was negatively correlated with mortality rate
Cano-Pérez 2020	observational study using national surveillance data	70 cities in Colombia with altitudes between 1 and 3,180 metres	6 March to 1 Aug 2020	altitude	incidence and case-fatality rate from COVID-19	the case fatality rate was negatively correlated with the altitude of the cities; the incidence of cases and deaths from COVID-19 had an apparent correlation with altitude; however, these variables were better explained by population density
Castilla J 2021	ecological study using seroprevalence of SARS-CoV-2 antibodies by province, obtained from a nationwide representative survey performed in June 2020.	50 provinces, Spain	June 2020	altitude	SARS-CoV-2 antibodies, indicating previous recent infection	altitude, which ranged from 5 to 1131 m, explained nearly half of differences in seroprevalence; the seroprevalence in people residing in provinces above the median altitude (215 m) was three-fold higher
Segovia-Juarez 2020	observational study using national surveillance data	Peru, 185 capitals of provinces with altitudes ranging from 3 to 4342 metres	January to June 2020	altitude	COVID-19 cases and case-fatality rate	case numbers of COVID-19 reduced at high altitude. Case-fatality rate not associated with altitude
Stephens 2021	observational study using population-scale regression analysis	US counties	27 May to 27 Aug 2020	higher altitude (elevation) counties (versus lower altitude counties)	COVID-19 infection rates	decreased COVID-19 infection rates by 12.82%, 12.01%, and 11.72% per 495m of county centroid elevation, for cases recorded over the previous 30, 90, and 120 days, respectively
Woolcott OO 2021	Retrospective analysis of population-level data	1,016 counties, US and 567 municipalities, Mexico	20 Jan to 13 April 2020	altitude	COVID-19 deaths	altitude was associated with COVID-19 mortality in men younger than 65 years
Table 1b. Exposure: air pollution						
Ademu LO 2022	observational study using state level meteorological data and hospital admissions data	20 counties in California, USA	1 February 2020 to 31 December 2020	PM2.5, carbon monoxide (CO), nitrogen dioxide (NO2), and Air Quality Index (AQI)	confirmed cases of COVID-19	PM2.5, CO, and AQI were positively associated with confirmed COVID-19 cases
Barnett-Itzhaki Z 2021	observational study using international surveillance data	36 OECD countries	January to June 2020	population-weighted long-term exposure to PM2.5 and NOx	daily COVID-19 morbidity and mortality	PM2.5 concentrations in 2015-2017 were positively correlated with COVID-19 morbidity and mortality on the 10th, 20th, 40th and 60th days since the first confirmed case in all countries; NOx concentrations in 2015-2017 and country's density (population/Km2) were positively correlated with COVID-19 morbidity and mortality on the 60th day; all multivariate linear regressions consisting PM2.5 concentrations models were statistically significant
Bontempi E 2020b	observational study using local meteorological data and surveillance data	Lombardy, Italy	10 February to 27 March 2020	PM10 concentration	cases of COVID-19 infections	the role of airborne PM for SARS-CoV-2 transmission was not evident
Braęoszewska E 2022	observational study using national surveillance data	Gliwice, Southern Poland	23 November 2020 to 31 March 2021	PM10 and PM2.5), sulfur dioxide (SO2), nitrogen oxides (NO and NO2), ozone (O3), and carbon monoxide (CO)	daily new cases of COVID-19	there was a significant positive correlation between NO2 concentrations and daily new cases; highest numbers of daily new cases were associated with the dominant wind directions in the region

Burnett 1999	observational study using local meteorological data and hospital admissions data	hospitals, Toronto, Canada	1980 to 1994	PM10; PM2.5; PM10-2.5, ozone, carbon monoxide, nitrogen dioxide, and sulfur dioxide	daily hospital admissions for respiratory, cardiac, cerebral vascular, and peripheral vascular diseases	analysis controlled for temporal trends and climatic factors, and found that increases of 10 µg/m ³ in PM10, PM2.5 and PM10 to 2.5 were associated with 1.9%, 3.3%, and 2.9% respective increase in respiratory and cardiac hospital admissions
Cohen 2005	burden of disease attributable to urban ambient air pollution was estimated in terms of deaths and disability-adjusted life years (DALYs)	Global (using WHO global burden of disease data)	2000	ambient air pollution, in terms of fine particulate air pollution (PM _{2.5})	cause specific mortality including acute respiratory infections	outdoor ambient air pollution, as estimated by fine particulate air pollution (PM _{2.5}), estimated to cause about 1% of mortality from acute respiratory infections in children under 5 yrs, worldwide
Di Biagio K 2022	observational study using national surveillance data	Marche region, Italy	February to May 2020	outdoor PM ≤ 10 µm (PM ₁₀)	SARS-CoV-2 infection incidence	10-years average exposure to PM ₁₀ was associated with an increased risk of new endemic and epidemic infection
Ghanim AAJ 2022	observational study using national surveillance data	Saudi Arabia	1 January to 30 June 2020	air pollutants including PM ₁₀ , NO ₂ , CO, SO ₂ , and O ₃	COVID-19 case numbers	number of recorded COVID-19 cases was highest in the most polluted regions; the mortality rate and critical cases were also higher in these regions; significant relationship between air pollution resulting from a high concentration of NO ₂ and COVID-19 infections and deaths
Karr 2007	case-control study	case-control study: patients with a hospital discharge for bronchiolitis in infancy were matched to 10 age- and gestational- age-matched controls; data were linked birth-hospital discharge records of infants born in the South Coast Air Basin of California, US	1995 to 2000	exposure in the month prior and lifetime exposure to air pollution PM _{2.5}	hospital discharge for bronchiolitis	subchronic and chronic PM _{2.5} exposures were associated with increased risk of bronchiolitis hospitalization after adjustment for confounders
Kim H 2022	case-crossover study	Cook County, Illinois, USA	Dec 2019 to 28 February 2021	PM 2.5 and O ₃ on the day of death and up to 21 days before death	COVID-19 deaths	higher air pollution was associated with higher death numbers
Manik S 2022	observational study using national surveillance data	metropolitan areas, India	26 April 2020 to 28 February 2021	ozone, PM ₁₀ , PM _{2.5} , carbon monoxide, sulfur dioxide, and nitrogen dioxide	daily confirmed cases COVID-10	correlation between daily confirmed cases with particulate matter PM 2.5 and PM 10; air quality index also showed a positive correlation with daily confirmed cases for most of the metropolitan Indian cities.
Marquès M 2021	observational study using national surveillance data	Tarragone Province, Catalonia, Spain	14 March 2020 to 8 May 2020	PM ₁₀ , NO ₂ and O ₃ ,	COVID-19 cases and deaths	data appeared too few to assess the relationship between air pollutants and COVID-19 cases and deaths
Meo SA 2020	observational study using local surveillance data	San Francisco, USA	20 March 2020 to 16 Sept 2020	particulate matter (PM _{2.5} µm) and carbon monoxide	COVID-19 cases and deaths	significant positive correlation between the environmental pollutants particulate matter (PM _{2.5} µm) and the number of daily cases, cumulative cases and cumulative deaths
Namdar-Khojasteh D 2022	observational study using national surveillance data.	Tehran city, Iran	long-term exposure data (60 months) September 2015 to September 2020; short-term exposure data (6 months) March 2020 to September 2020; outcome data March 2020 to September 2020	short-term (6-month) and long-term (60-month) exposures to eight air pollutants (NO, NO ₂ , NO _x , CO, SO ₂ , O ₃ , PM _{2.5} and PM ₁₀)	confirmed COVID-19 cases (determined by chest computed tomography and RT-PCR of respiratory secretions)	higher COVID-19 incidence rate was significantly associated with exposure to higher concentrations of CO, NO, and NO _x during the short-term period; higher COVID-19 incidence rate was significantly related to the exposure to higher concentrations of PM _{2.5} during the long-term period; while COVID-19 incidence rate was not significantly associated with concentrations of O ₃ , SO ₂ , PM ₁₀ and NO ₂ in either period

Páez-Osuna F 2021	observational study using national surveillance data.	Sinaloa, Northwest Mexico	February 2020 to April 2021	particulate matter (and wind speed)	COVID-19 cases and deaths	municipalities with high PM2.5 emissions and high population density have a higher COVID-19 mortality rate; high COVID-19 mortality rates of rural municipalities were associated with dust events; the influence of wind speed on COVID-19 mortality rate was evidenced only in municipalities with <100 inhabitants per km2
Setti L 2020	observational study using national surveillance data.	110 provinces, Italy	24 February to 13 March 2020	ambient PM10 levels	COVID-19 incidence	significant association was found between the geographical distribution of daily PM10 exceedances and the initial spreading of COVID-19
Singh RK 2021	observational study using international surveillance data.	USA, India, Brazil, Russia, France, Spain, Argentina, UK, Colombia, Mexico.	25 January to 31 January 2020; 25 May to 31 May 2020; 25 October to 31 October 2020.	air pollutants including CO, NO2, SO2, aerosols and O3	COVID-19 rates (study also looked at patterns of pollution resulting from lockdowns etc)	five of the ten included countries: USA, India, Russia, Brazil and UK are also amongst those with the worst quality of air
Yao Y 2021	observational study using national surveillance data.	63 Chinese cities	1 January 2020 to 8 February 2020	ambient nitrogen dioxide pollution	COVID-19 incidence and estimated reproduction rate	basic reproductive number of COVID-19 was positively associated with NO2 after adjustment for temperature and relative humidity.
Zhang X 2021	observational study using national surveillance data.	235 Chinese cities	29 Dec 2019 to 6 April 2020	PM2.5, PM10, and nitrogen dioxide (NO2)	daily new COVID-19 case numbers	increase in PM2.5, PM10, and NO2 were associated with increases in the counts of daily onset cases
Zhou X 2021	observational study using regional surveillance data	92 western US counties that were affected by the 2020 wildfires	15 March to 16 December 2020	PM 2.5	COVID-19 case numbers and deaths	strong evidence that wildfires amplified the effect of short-term exposure to PM2.5 on COVID-19 cases and deaths, although with substantial heterogeneity across counties
Zoran MA 2020a	observational study using national surveillance data.	Milan metropolitan area, Italy.	January to April 2020	daily average inhalable gaseous pollutants ozone (O3) and nitrogen dioxide (NO2)	COVID-19 daily new cases and deaths	COVID-19 viral infections were positively correlated with ground level ozone. Ground level nitrogen dioxide was inversely correlated with COVID-19 infections
Zoran MA 2020b	observational study using national surveillance data.	Milan metropolitan area, Italy.	1 January to 30 April 2020	Daily average concentrations of inhalable particulate matter (PM) in two size fractions PM2.5, PM10 and maxima PM10 ground level atmospheric pollutants	COVID-19 daily new cases and deaths	positive correlations between all confirmed COVID-19 daily new cases in Milan and air pollution with daily maxima PM10, daily average surface air PM2.5, daily AQI
Table 1c. Exposure: air temperature						
Aboubakri O 2022	observational study using national surveillance data	Iran	February 2020 to April 2021	spatio-temporally kriged land surface temperature and air temperature	Covid-19 transmission	land or air temperature were not statistically important predictors of Covid-19 transmission.
Guo C 2021	observational study using national surveillance data; interrupted time-series model with a state-level random intercept	50 states and one territory of the US	29 January and 31 July 2020	temperature (as well as physical distancing interventions)	COVID-19 case number increases	increased temperature was associated with decreased growth rate of case numbers; there was a statistically significant interaction between temperature and physical distancing implementation.
Habib G 2022	observational study using national surveillance data	Pakistan	March to December 2020	temperature	COVID-19 case numbers	when the temperature remained high for consecutive 10 to 15 days, a significant decrease in COVID-19 cases was observed the following week. A persistent high ambient temperature of 36 °C was associated with lower SARS-CoV-2 transmission. High relative humidity of 63-72% was associated with lower SARS-CoV-2 transmission
Hassan M 2020	ecological study	global	January to 21 March 2020	temperature	COVID-19 cases	there was a significant correlation between decreased attack rate and increased environmental temperature

Hu C-Y 2021	observational study using correlations and applying regression models	6 cities in Hubei Province, China	2020	daily temperature	daily newly confirmed COVID-19 cases	between -3.9 to 16.5°C, daily newly confirmed cases were positively correlated with the maximum temperature 0 to 4 days prior or the minimum temperature 11 to 14 days prior to diagnosis most cities; the influence of temperature on the daily newly confirmed cases in Wuhan was much more significant than in other cities
Huang Z 2020	observational study using international surveillance data	185 countries /regions	January 21, 2020 to May 6, 2020	temperature	COVID-19 cases	60% of COVID-19 cases occurred in places where the air temperature ranged from 5 °C to 15 °C, with a peak in cases at 11.54 °C; 74% of confirmed cases were concentrated in regions with absolute humidity of 3 g/m ³ to 10 g/m ³
Irfan M 2021	observational study using national surveillance data; grey incidence analysis	Pakistan	17 June 2020 to 31 December 2020	temperature	COVID-19 cases	results suggest that low temperatures were associated with high COVID-19 transmissibility
Irfan 2022	observational study using national surveillance data	India	April to October 2020	air temperature	COVID-19 case numbers	heterogeneous relationship of air temperature and case numbers
Jacobs EZ 2022	observational study using national surveillance data	Nigeria	27 February to 22 December 2020	temperature	COVID-19 incidence	no significant and positive relationship was observed between COVID-19 incidence and temperature variables
Jahangiri 2020	observational study using national surveillance data	31 provinces, Iran	15 February 2020 to 22 March 2020.	ambient temperature (and population size)	no. of COVID-19 cases	ambient temperature was not clearly related to COVID-19 cases across the regions.
Kassem 2020	observational study, using non-linear least squares method	43 countries: 1) 13 with first COVID-19 cases in January 2020; 2) 13 with first case in Feb 2020; 3) 17 countries with first case in March 2020	Jan to July 2020	temperature	COVID-19 cases per million	inverse relationship between temperature and COVID-19 cases per million
Kumar A 2020	observational study using international data, using multivariable two-level negative binomial regression	67 countries	31 December 2019 to 3 April 2020	environmental temperature (and neonatal BCG vaccination coverage)	transmissibility and fatality rate of COVID-19	high temperature was not associated with low transmissibility (and countries having neonatal BCG vaccination policy had a low fatality rate of COVID-19)
Lin K 2006	observational study using national surveillance data	Hong Kong, China	11 March to 22 May 2003	air temperature	Severe acute respiratory syndrome (SARS) daily confirmed cases.	in days with a lower air temperature during the epidemic, the risk of increased daily incidence of SARS was 18-fold higher than in days with a higher temperature
Liu M 2022	observational study using international surveillance data	153 countries	1 March 2020 to 5 May 2020	temperature	COVID-19 case numbers	temperature was positively related to daily new cases at low temperature but negatively related to daily new cases at high temperature
Monami 2020	observational study using international surveillance data	global	29 Dec 2019 to 9 March 2020	air temperature	COVID-19 case numbers	the number of cases per million inhabitants, showed a significant inverse correlation ($r = -0.23$, $p = 0.001$) with average temperatures in February
Notari A 2021	observational study using international surveillance data	global	January to April 2020	temperature	COVID-19 case numbers	there was an association between higher temperature and slower increase in case numbers
Prata DN 2020	observational study using national surveillance data	all 27 state capitals, Brazil	27 February to 1 April 2020	temperature	daily cumulative confirmed cases of COVID-19	results indicated that temperatures had a negative linear relationship with the number of confirmed cases
Shi P 2020	retrospective observational study using national surveillance data	31 provincial-level regions, mainland China	20 Jan to 29 Feb 2020	daily mean temperature	COVID-19 daily confirmed cases	daily confirmed cases rate of COVID-19 had a biphasic relationship with temperature (with a peak at 10 °C), and the daily incidence of COVID-19 decreased at values below and above these values
To T 2021	observational study using national surveillance data	Alberta, British Columbia, Ontario, and Quebec, Canada	January to May 2020	ambient temperature	COVID-19 cases	no significant association between ambient temperature and COVID-19 incidence

Tobias 2020	observational study using national surveillance data	Barcelona's Health Region, Spain	2 March to 5 April 2020.	temperature	COVID-19 cases	an average increase of 1 °C of maximum temperature was associated with decreased incidence rate by 7.5% on the same day (lag day 0); subsequently, the temperature association was substantially reduced between lag day 1 to lag day 6
Usmani M 2022	observational study using national surveillance data, time series analysis	Daegu, South Korea; Munich, Germany; Tehran, Iran; and Wuhan, China)	Dec 2019 to Oct 2020	ambient air and dew point temperatures	COVID-19 cases	under a dry (low-moisture) environment, notably at dew point temperatures below 0°C, the incidence of the disease was highest; an ambient air temperature range of 17 to 24°C was identified, within which virus transmission appears to decrease, leading to a reduction in COVID-19 human cases
Wang Q 2021	observational study using national surveillance data	28 provincial level regions in China	20 January to 29 February 2020	temperature	COVID-19 cases	study found little statistical evidence for that the higher temperature may reduce the transmissibility of COVID-19
Yamasaki 2021	observational study using national surveillance data	Tokyo, Japan	15 Feb 2020 to 28 Feb 2021	environmental temperature	COVID-19 effective reproduction rate and case fatality rate	low temperature was associated with higher reproduction rate; a U shaped curve of environmental temperature with case fatality rate
Yu X 2020	observational study using national surveillance data	30 metropolitan areas, USA	29 Dec 2019 to 15 July 2020	(NPIs and) temperature	COVID-19 cases reproduction rate	cities with warm temperature tended to have a lower peak reproduction rate than that of cities with cold temperature. However, this were not statistically significant and large geographic variations existed.
Zhang R 2022	observational study using national surveillance data	30 cities, China	2016 to 2019	ambient temperature	daily influenza incidence	overall, an N-shape relationship between temperature and influenza incidence was found in China; increases in influenza incidence attributed to temperature changes were most notable among the youngest groups
Zilberlicht 2021	observational study using international surveillance data/ observational retrospective study	202 countries	day 14 and day 28 since first reported case of COVID-19 for each country, respectively	air temperature	cumulative cases and deaths from COVID-19	air temperature negatively correlated with cumulative cases and deaths (population age correlated positively with cumulative cases and deaths)
Table 1d. Exposure: temperature and humidity						
Akbar F 2022	observational study using national surveillance data	Pakistan	1 March to 30 September 2020	temperature, humidity	COVID-19 case numbers	temperature average and average humidity were not significantly correlated with COVID-19 case numbers
Anam S 2021	observational study using international surveillance data	24 cities in 8 countries: Afghanistan, Bangladesh, China, India, Japan, Pakistan, South Africa, USA,	Dec 2019 to July 2020	temperature, humidity	COVID-19 cases	higher temperature was associated with lower COVID-19 cases; the effect of humidity was not significant
Berumen J 2020	Retrospective study based on the WHO registry of cumulative incidence of COVID-19 cases	1,706,914 COVID-19 cases in 67 countries grouped by climate zone	29 Dec 2019 to 15 April 2020	temperature, humidity	COVID-19 cases	doubling time was longer in tropical vs non tropical zones and was related to temperature
Boufekane A 2022	observational study using national surveillance data	14 cities in Algeria	1 April to 31 August 2020	temperature, humidity	daily new cases of COVID-19	possible correlation of temperature and relative humidity and daily new confirmed cases
Bukhari 2020	observational study using international surveillance data: correlations investigated	all global regions with COVID-19 cases; 3 million cases	Dec 2019 to 1 May 2020	temperature, absolute humidity	COVID-19 case numbers	approx 85% of the 3 million COVID-19 cases occurred in regions with temperature between 3 and 17 degree C, & absolute humidity between 1 and 9 g/m3
Fang L-Q 2020	retrospective observational study using national surveillance data	305 cities outside Hubei Province, China	31 December 2019 to 27 April 2020	temperature, humidity (and lockdown restrictions)	daily effective reproduction numbers of COVID-19	higher local transmissibility of COVID-19 was associated with a low temperature, high humidity (as well as higher intracity and intercity human movement)

Feng F 2022	observational study using national surveillance data	11 cities, China	21 January to 29 February 2020	temperature, humidity represented by the discomfort index	COVID-19 case numbers	there was a significant negative correlation between the discomfort index and daily COVID-19 cases, except in Wuhan; the lag effect was stronger in the cities located further north; in northern cities, each unit decrease in the discomfort index increased the COVID-19 risk from 7 to 13 lag days; in southern China, each unit decrease in the discomfort index increased the COVID-19 risk from 0 to 7 lag days, especially in Shanghai, Guangzhou, and Shenzhen
Fu S 2021	observational study using national-specific and region-specific data sets	Germany, Italy, Spain and the United Kingdom	1 February to 1 November 2020	temperature, absolute humidity and diurnal temperature range	COVID-19 case doubling time	cold and dry environments were associated with shorter case doubling times of COVID-19 in these four European countries
Gao M 2021	observational study using international surveillance data	45 countries globally	January to March 2020	temperature and humidity	COVID-19 case numbers	stronger transmission of COVID-19 under mildly warm ($0^{\circ}\text{C} < T < 20^{\circ}\text{C}$) and humid ($\text{RH} > 60\%$) climate conditions, while extremely low ($T < -2^{\circ}\text{C}$) and high ($T > 20^{\circ}\text{C}$) temperature or a dry climate ($\text{RH} < 60\%$) weakens transmission
Gardinassi LG 2012	cross sectional study using clinical samples	children aged one month to six years attending Sao Jose do Rio Preto tertiary hospital, suffering from ARI: nasopharyngeal wash samples collected on admission and tested by RT-PCR	May 2004 and September 2005	temperature, humidity	human respiratory syncytial virus, human metapneumovirus, influenza virus A and B, human parainfluenza virus 1, 2 and 3 and human rhinovirus	viral respiratory infections tended to increase as the relative air humidity decreased, showing significant association with monthly averages of minimal temperature and minimal relative air humidity
Guo X-Y 2020	observational study using national surveillance data	Beijing, Shanghai, Guangzhou, and Chengdu, China	18 January 18 February 2020 to 13 February 2020	temperature, humidity	estimated reproduction rate for COVID-19 cases (based on transmission data)	estimated reproduction rate for COVID-19 was negatively correlated with both temperature and humidity, which was significant at the 0.01 level
Gupta S 2020	observational study using national surveillance data	50 US states	1 Jan to 9 Apr 2020	temperature and absolute humidity	daily new cases of COVID-19	over 50% of new cases were observed in states with a narrow range of AH between 4 and 6 g/m ³ , and 15% were in states with AH >9g/m ³ ; there was no clear pattern for temperature
Gurram MK 2022	observational study using national surveillance data	Singapore	21 January 2020 to 17 March 2020	temperature, relative humidity (also population density and urbanisation)	daily new cases of COVID-19	during the early phase of COVID-19 epidemic in Singapore, significant but weak correlation of temperature with COVID-19 incidence (significance 0.5–1.5) was observed in several sub-zones of Singapore; correlations between humidity and incidence could not be established; across sub-zones, high residential population density and high levels of urbanisation were associated with COVID-19 incidence
Gurav YK 2017	observational study using regional surveillance data	Pune, India	2012 to 2015	temperature, relative humidity	ILI and influenza H1N1	rise in ILI cases was negatively correlated with seasonal factors such as relative humidity in the year 2012 and 2015, while rise in ILI cases was positively correlated with the temperature difference in the year 2012 and 2015
Haque SE 2020	observational study using national surveillance data	Bangladesh	8 March 2020 to 3 May 2020	temperature, humidity	COVID-19 confirmed cases	peak spread of COVID-19 occurred at an average temperature of 26 °C; high temperature and high humidity were significantly associated with reduced transmission of COVID-19
He Z 2021	time-series analysis using Pearson correlation and generalised additive modelling	Japan, Korea, Malaysia, Singapore; and 5 cities in China: Wuhan, Beijing, Shanghai, Guangzhou, Hong Kong	2 Jan to 18 March 2020	average temperature and relative humidity	daily new confirmed cases of COVID-19	high temperature was associated with higher daily new cases; high relative humidity was significantly associated with slightly reduced daily cases

Hudiyanti CV 2021	observational study using national surveillance data	Surabaya, Indonesia	22 August 2020 to 5 April 2021	temperature and humidity	daily new confirmed cases of COVID-19	air temperature correlated with the number of daily suspected cases; air humidity did not correlate with the number of confirmations, suspect or probable COVID-19 cases
Karim R 2022	observational study using national surveillance data	Bangladesh	8 March 2020 to 31 January 2021	temperature and humidity	daily number of SARS-CoV-2 infected new cases, and the number of death due to Covid-19	temperature was highly significantly associated with number of SARS-CoV-2 infected new cases and number of deaths due to COVID-19; humidity was significantly associated with the number of SARS-CoV-2 infected new cases
Makama EK 2021	observational study using national surveillance data	Kuala Lumpur, Malaysia	14 March 2020 to 31 August 2020	ambient temperature and absolute humidity	new daily COVID-19 infections	the relationship between temperature and new daily cases was linear and statistically significant for temperatures > 29.7°C; absolute humidity below ≤ 22.6 g/m ³ had a more pronounced linear association with new daily cases but tended to flatten the exposure-response curve above this value
Manik S 2022	observational study using national surveillance data and time dependent epidemiological models	India	1 Feb 2021 to 10 Oct 2021	air temperature, humidity	new daily COVID-19 infections	effective reproduction number showed a statistically significant negative correlation with both relative and absolute humidity for most of the Indian states; six out of ten states showed a positive correlation while two (out of ten) showed a negative correlation between effective reproduction number and average air temperature
Meyer A 2020	observational study using international surveillance data	global	29 Dec 2019 to 17 March 2020	air temperature and relative humidity	daily incidence of confirmed COVID-19 local cases	after adjusting for surveillance capacity and time since first imported case, average temperature had a statistically significant, negative association with COVID-19 incidence for temperatures of $\sim 15^\circ\text{C}$ and above; temperature only explained a relatively modest amount of the total variation in COVID-19 cases; the effect of relative humidity was not statistically significant
Moustafa AA 2020	observational study using national surveillance data	Egypt	1 March to 5 August 2020	temperature, humidity	cases of COVID-19	minimum temperature was significantly associated with the increase of infected cases of COVID-19; minimum, maximum and relative humidity showed a positive significant relationship with the number of daily infected cases
Mozumder 2021	observational study using generalised regression model	New York City, USA	8 March 30 April 2020	temperature and relative humidity	change in daily new cases of COVID-19	no significant correlation between temperature, humidity, and change in number of COVID-19 cases; the number of total deaths was also higher in low temperature countries compared with high-temperature countries
Ogaugwu C 2020	observational study using national surveillance data	Nigeria	9 March to 12 May 2020	temperature and humidity	COVID-19 incidence rate and mortality.	atmospheric temperature had a significant weak negative correlation with COVID-19 transmission; also, a significant weak negative correlation was found between temperature and cumulative mortality; no significant association was found between atmospheric humidity and COVID-19 transmission or mortality.
Olinto MTA 2022	observational study using national surveillance data	state capital cities in Brazil and the Federal District (Brasília), Brazil	20 February to 18 April 2020	mean temperature, temperature amplitude, mean relative humidity, relative humidity amplitude, and percentage of days with mean relative humidity $\leq 65\%$.	COVID-19 incidence rate	lower mean relative humidity was correlated with a lower number of cases and deaths in Brazil, especially when the relative humidity was $\leq 65\%$; higher temperatures and humidity amplitudes were correlated with lower COVID-19 mortality; additionally, after controlling for humidity, cumulative cases of COVID-19 were inversely associated with temperature in cities with mean temperatures less than 25.8°C

Panigrahi A 2021	observational study using national data	38 districts of India	1 April 2020 to 30 April 2020	temperature and humidity	COVID-19 daily cases rate of increase	increased temperature was associated with a reduced percent increase in COVID-19 cases; as relative humidity increased there was a significant increase in percent increase in COVID-19 cases
Poirier 2020	observational study using international surveillance data	Iran, Italy, Singapore, Japan, and South Korea and 345 cities in China.	22 January 22 to 26 February 2020	temperature, humidity (and human mobility)	COVID-19 cases	observed spatial patterns of COVID-19 transmission were not explained by ambient temperature, absolute humidity or human mobility alone
Raines KS 2021	observational study using national surveillance data	Colombia	January to March 2020	temperature, humidity	COVID-19 cases	there was strong attenuation of transmission in climates with sustained daily temperatures above 30 degrees Celsius and simultaneous mean relative humidity below 78%, with outbreaks occurring at high humidity even where the temperature was high
Ran J 2020	national ecological study (observational study using national surveillance data)	154 cities in China	December 2019 to February 2020	mean temperature, relative humidity	COVID-19 case numbers	ambient temperature was found to have a nonlinear negative association with COVID-19
Rashad 2020	observational study using national surveillance data	16 prefectures in Japan	15 March to 25 May 2020	absolute humidity, temperature (and population density)	COVID-19 case numbers	population density was shown to be a major factor, affecting the spread and decay patterns; maximum absolute humidity was found to affect the decay duration normalized by the population density
Ravelli E 2022	observational study using national surveillance data	The Netherlands	2015 to 2019 for influenza; 13 March to 9 July 2020 for COVID-19.	specific humidity	influenza cases, and COVID-19 cases, hospitalizations, and deaths.	inverse (negative) relationship was observed between specific humidity and the incidence of influenza between 2015 and 2019; space-time analysis indicated that an increase of specific humidity of one gram of water vapor per kilogram of air (1 g/kg) was related to a reduction of approximately 5% in the risk of COVID-19 infections
Ren M 2021	observational study using national surveillance data	China	23 January to 21 February 2020	temperature and humidity	COVID-19 transmission rates	higher temperature was most strongly associated with decreased COVID-19 transmission at a lag time of 8 days relative humidity (RH) appeared to have only a slight association
Si X 2021	observational study using national surveillance data	Wuhan, China	14 January 2020 to 17 March 2020	daily average temperature and average relative humidity	COVID-19 transmission rates	temperature was negatively associated with COVID-19 transmissibility during early stages of the outbreak in Wuhan
Soebiyanto 2014	observational study using national surveillance data	6 study areas that included 11 departments or provinces within 3 tropical Central American countries: Guatemala, El Salvador and Panama.	2008 to 2013 (excluding pandemic year 2009)	temperature and humidity	weekly proportion of laboratory-confirmed influenza positive samples	positive association with humidity was found in El Salvador and Panama; negative association was found in the more subtropical Guatemala, similar to temperate regions

Tamerius 2017	cohort study of households with an index case: ppts visited every 2–3 days up to 5 times over 10–14 days; nose & throat swab samples collected; daily symptoms recorded; respiratory samples tested for influenza type by RTPCR	34 households with index case of influenza, Managua, Nicaragua	24 July to 31 October 2014	indoor temperature and humidity	influenza as identified by RTPCR of respiratory samples	15 suspected transmission events appeared to occur at 29 °C, 18 g/kg specific humidity, and 68 % relative humidity
Wang J 2021	retrospective cross-sectional regression analysis via the Fama-MacBeth procedure	100 Chinese cities and 1005 US counties	Jan to Feb 2020	temperature and relative humidity	effective reproduction number of SARS-CoV-2	statistically significant negative correlations between temperature/relative humidity and the effective reproductive number in both China and USA
Ward MP 2021	observational study using national surveillance data	Sydney, Australia	16 June to 10 September 2021	temperature, humidity	COVID-19 cases	humidity was negatively associated with cases no matter whether temperature was high or low; the effect of lower relative humidity on increased cases was more pronounced below relative humidity of about 70%
Wu Y 2020	observational study using international surveillance data	166 countries	Dec 2019 to 27 March 2020	temperature, humidity	cases of and deaths from COVID-19	temperature and relative humidity were both negatively related to daily new cases and deaths
Yang L 2011	observational study using national surveillance data; Poisson regression models applied	Guangzhou and Hong Kong, China (subtropical region)	1998-2006	humidity, temperature	deaths from pneumonia or influenza	absolute humidity and temperature were not associated with increased risks of pneumonia and influenza deaths
Zhang C 2021	observational study using international surveillance data	1236 regions of the world	29 Dec 2019 to 31 May 2020	temperature, humidity	COVID-19 cases	average daily temperature was significantly negatively correlated with the new daily cases; higher relative humidity was associated with lower new case numbers
Table 1e. Exposure: season, seasonality						
Al-Abdallat M 2015	longitudinal hospital based study over 6 years	2,891 patients with acute respiratory infections identified by symptoms and tested with nasopharyngeal or oropharyngeal swabs using RT-PCR	January 2008 to February 2014	season	influenza A or B, with influenza A further subtyped	the seasonal pattern of influenza aligned with known Northern Hemisphere seasonality; the proportion of influenza-positive cases peaked during November–January (14–42%) in the non-pandemic years
Aldridge RW 2020	prospective community cohort study over 5 years (FluWatch)	healthy cohort recruited into the study and followed weekly for symptoms and laboratory confirmed respiratory infections, England	2006-2007, 2007-2008, 2008-2009	season	PCR-confirmed coronavirus infections (HCoV-NL63, HCoV-OC43, and HCoV-229E)	evidence that HCoV infection in England is most intense in winter, with a small amount of ongoing transmission during summer periods; rate of confirmed HCoV infection was highest in the Nov-Mar 2008/9 season; the highest rate was in February 2009; there was small amounts of ongoing transmission in summer 2009.
Alonso WJ 2007	observational study using national surveillance data	Brazil	1979 to 2001	season	pneumonia and influenza mortality	seasonality in mortality was most pronounced in southern states (winter epidemics, June-July), gradually attenuated toward central states, and remained low near the equator; a seasonal southward traveling wave of influenza was identified across Brazil, originating from equatorial and low-population regions in March-April and moving toward temperate and highly populous regions over a 3-month period
Althouse BM 2018	hospital based enhanced surveillance of using clinical samples; RT-PCR used to detect 13 respiratory viruses in nasopharyngeal samples.	paediatric acute respiratory infection patients treated at Khanh Hoa General Hospital in Nha Trang, Vietnam	129 January 2007 to 26 April 2012	season	influenza A, influenza B, RSV, hMPV, PIV-1, -2, -3, -4; rhinovirus, coronavirus 229E, coronavirus OC43; adenovirus, bocavirus	respiratory syncytial virus peaked in the late summer months, and influenza A in April to June

Al-Tawfiq 2019	retrospective observational study using national and WHO surveillance data	Saudi Arabia	January 2013 to December 2017	season	primary MERS-CoV cases	no definite seasonal variation of primary MERS-CoV cases despite initial peak in February and August 2015 and in March 2017
Annan A 2016	observational study using two sets of clinical samples tested by molecular detection methods.	1,174 Ghanaian and 539 German children <13 years of age with acute respiratory infections each sampled with nasopharyngeal flocked swab, tested by PCR	February 2008 to February 2009	season	15 most common respiratory viruses: enveloped viruses under study included Flu A/B, pneumoviruses, hPIV1–4 and hCoV. Non-enveloped viruses included EV, RhV and AdV.	in the Ghanaian rainy season, enveloped viruses were detected twice as often as non-enveloped viruses; non-enveloped viruses were more frequent during the Ghanaian dry season; in Germany, enveloped viruses were also more frequently detected during the relatively colder winter season and non-enveloped viruses during summer
Belizaire MRD 2022	observational study using international surveillance data	Africa	2013-2019	season	influenza: influenza A(H1N1)pdm2009, A(H3N2), and A(H5N1) viruses, as well as influenza B Victoria and Yamagata lineages	influenza activity followed annual and regional variations; in the tropical zone, from eastern to western via the middle regions, influenza activities were marked by the predominance of influenza A subtypes despite the circulation of B lineages; one season was identified for both the southern and northern regions of Africa; in the eastern zone, four influenza seasons were differentiated, and three were differentiated in the western zone
Caini S 2019	observational study using respiratory samples collected within the national surveillance program	41,172 nasopharyngeal swab specimens collected from all ILI and SARI patients presenting at all hospitals, local health units, airports and harbours in Ecuador	2009 to 2016	season	influenza viruses, respiratory syncytial virus (RSV), adenovirus, parainfluenza virus, and human metapneumovirus	influenza epidemics typically peaked in December–January and RSV epidemics in March; seasonality was less evident for the other viruses
Chadha M 2020	global pilot surveillance program using clinical samples	inpatient and outpatient clinical treatment centres in 14 countries; patients all ages who presented with cough and hospitalization; infants < 6 months presenting with sepsis or apnea also eligible, as RSV presents with these conditions in this age group; WHO ARI case definition was used at outpatient sites.	January 2017 to April 2019	season	RSV	early findings from the WHO RSV surveillance pilot suggest annual seasonal patterns for of RSV circulation that overlap with influenza; RSV surveillance needs to be continued for several more seasons to establish seasonality patterns
Coletti 2018	observational study using data collected by the French Surveillance Network of general practitioners (Reseau Sentinelles)	22 regions of France	30 influenza seasons, ranging from 1984–1985 season to 2013–2014 season, and including the H1N1 pandemic season of 2009–2010	season	influenza-like-illness incidence data	large variability was observed across seasons; peak times ranges from week 49 (month of December, seasons 1993–94, 2003–04 and 2009–10) to week 14 (Month of April, seasons 1994–95 and 1997–98), with 9 of the seasons peaking before week 2 in January (denoted here as early seasons) vs. 21 peaking after week 6 (late seasons, while peaks between week 2 and week 6 were named winter seasons in the following)
Dzien 2020	retrospective analysis of primary care patient records	15,336 patients (8,907 men and 6,429 women) attending a primary care practice in Innsbruck, Austria including 16,317 assigned as acute respiratory diseases	1 July 1999 to 15 March 2020	season	respiratory infections	respiratory infections including human corona viruses followed a seasonal pattern: peaked during winter time and early spring

Evangelista AT 2022	observational study using clinical sample analysis	nasopharyngeal swabs obtained from admitted paediatric patients with worsening respiratory symptoms, hospital, Philadelphia, USA.	2013 to 2020	season	influenza A, influenza B, and endemic human coronaviruses (HKU1, OC43, NL63, 229E)	the 8-year average peak activity of human coronaviruses occurred in the first week of January; disease incidence was reduced by 50% in early March, to 75% in early April, to greater than 99% at the end of April, a relationship was observed from colder outdoor temperatures in January with a low indoor relative humidity to a gradual increase in outdoor temperatures in April with an indoor relative humidity up to 50%
Famoroti T 2018	retrospective analysis of laboratory test results of upper or lower respiratory specimens	children between 0 and 5 years of age attending hospitals in KwaZulu-Natal, South Africa	1 January 2011 to 31 July 2015	season	adenovirus, enterovirus, human bocavirus (HBoV), parainfluenza viruses 1 and 3 (PIV1 and 3) influenza A 9FluA), respiratory syncytial virus (RSV)	a seasonal time series pattern was observed for adenovirus (winter peak), enterovirus (autumn), human bocavirus (HBoV) (summer), and parainfluenza viruses 1 and 3 (PIV1 and 3) (spring); stationary or untrended seasonal variation was observed for FluA (winter peak) and RSV (summer)
Finianos 2016	longitudinal study over 1 year: nasal and throat swabs were collected from 236 pediatric patients, aged 16-year old or less and hospitalized for acute respiratory illness	Makassed General Hospital, Lebanon	October 2013 to September 2014	season	17 respiratory viruses	pathogens were most frequently observed during fall and winter seasons
Freitas ARR 2016	observational study using national influenza sentinel surveillance data including clinical sample analysis by immunofluorescence	12,501 nasopharyngeal samples collected from children under 5 years old as part of national disease surveillance system across 5 regions of Brazil	2005 to 2012	season	rate of hospitalisations per bronchiolitis and pneumonia due to RSV in children under 5 years old	a strong trend for annual cycles with a stable stationary pattern in the five regions was identified; the RSV peak occurred in the North and Midwest regions in the second week of April, in the Northeast in the first week of May, in the Southeast in the beginning of April, and in the South in the first week of June.
Garcia-Arroyo L 2022	retrospective study: all respiratory clinical specimens sent for analysis at the hospital laboratory (nasopharyngeal aspirates, nasal and pharyngeal exudates, bronchoalveolar lavages, and lung biopsies) analysed for respiratory viruses	respiratory samples sent for analysis in hospital laboratory, Barcelona, Spain	1997 to 2020	season	respiratory syncytial virus (RSV), adenoviruses (AdV), influenza virus types A and B (FLUAV and FLUBV), human metapneumovirus (hMPV), parainfluenza virus types 1–3 (PIV-1, PIV-2, and PIV-3), rhinoviruses (RV), enteroviruses (EV), and coronaviruses (CoV)	number of positive samples during cold months was significantly higher than in warm months; clear demographic and seasonal pattern established for some viruses: RSV detection highest from November to January, maximum in December; prevalence of FLUAV highest from December to March, typically reaching a peak in January; for FLUBV, it was January to March, with a peak usually 1 month after FLUAV; hMPV most prevalent from February to May, and PIV-2, from September to December, with a peak usually in November; other respiratory viruses in this study were detected throughout the year: AdV most prevalent from November to May; EV and RV usually peaked in autumn and spring; PIV-1, from September to April with a peak in October; and PIV-3, from April to June and October to December
Gülen F 2014	observational study using clinical samples tested using shell-vial cell culture method and direct fluorescent antibody test and/or multiplex PCR test.	nasopharyngeal swab samples obtained from 1,326 patients with suspected respiratory tract infection who presented to Ege University, Medical Faculty Children's Hospital, Turkey	2002 and 2012	season	Influenza virus type A and B, respiratory syncytial virus, adenovirus and parainfluenza virus type 1-3	parainfluenza and respiratory syncytial virus were found most frequently in December-february (58% and 59%, respectively, influenza viruses were found most frequently in November-December (72%) and adenoviruses were found most frequently in May-September (56%)

Gordon A 2009	prospective 2-year cohort study (part of ongoing dengue study); healthy children recruited and enrolled; nasopharyngeal swabs taken for those reporting influenza-like symptoms during the 2 year follow-up, samples tested by PCR.	4,276 children, 2-11 years of age, Managua, Nicaragua	April 2005 to April 2007	season	influenza-like-illness incidence data	ILI episodes occurred with marked seasonality; they peaked during June–July in both years and again during November–December of the second year
Hawkes 2021	observational cohort study (also leading to predictive modelling)	37,719 patients with medically attended respiratory tract infection in Alberta, Canada.	2005 to 2017	seasonality	RSV, human metapneumovirus, or human coronaviruses 229E, NL63, OC43, or HKU1 (incidence of respiratory virus infections and hospitalizations for RSV)	strong biennial variation in incidence was observed with alternating severe and mild winter peaks; among children <5 yrs, hospitalizations were considerably higher in alternating severe seasons
Hope-Simpson 1981	observational study using global surveillance data	Global	1964 to 1975	season	influenza	in both north and south temperate zones, outbreaks were grouped around the time of local midwinter; in tropical zones the outbreaks showed transition between the timings in the temperate zones
Horton KC 2017	Sentinel surveillance study using nasopharyngeal and oropharyngeal swabs	hospitalized patients meeting severe acute respiratory infection (SARI) case definitions in 20 hospitals in Egypt, Jordan, Oman, Qatar and Yemen	December 2007 to February 2014	season	influenza, respiratory syncytial virus (RSV), adenovirus (AdV), human metapneumovirus (hMPV) and human parainfluenza virus types 1–3 (hPIV1-3)	monthly variation, indicating seasonal differences in levels of infection, was observed for all pathogens
Jayaweera JAAS 2021	observational study using clinical samples: nasopharyngeal aspirates were collected; respiratory viral antigen detection by immunofluorescence assay was used to identify the infecting viruses.	hospitalized children (1 month-5 years) with acute respiratory tract infection in 2 centers (wet and dry zones), Sri Lanka	March 2013 to August 2014	season	human metapneumovirus (hMPV), human bocavirus and corona, respiratory syncytial virus (RSV), adenovirus, parainfluenza virus 1,2,3; influenza A and B	peak viral detection was noted in the wet zone from May-July 2013 and 2014 and in the dry zone from December-January 2014 suggesting a local seasonality for viral ARTI; RSV showed a clear seasonality with a direct correlation of monthly RSV infections with rainy days in the wet zone and an inverse correlation with temperature in both locations
Lekana-Douki 2014	surveillance network: nasal swabs collected from patients with ILI and tested	4 towns in Gabon (Libreville, Franceville, Oyem and Koumoutou); 1,041 specimens collected and tested	March 2010 and June 2011	season	17 respiratory viruses: adenovirus, parainfluenza virus 4, respiratory syncytial virus, human metapneumovirus, parainfluenza virus 1, parainfluenza virus 2, pandemic influenza virus A, seasonal influenza virus A (H1N1, H3N2), seasonal influenza virus B, human coronaviruses 229E/OC43, human coronaviruses NL63, HKU1, rhinovirus, human parechovirus, enterovirus, parainfluenza virus 3	adenovirus was detected at a stable rate throughout the study; among the human coronaviruses, only OC43 showed significant variation between dry and rainy season
Leotte J 2017	cross sectional study using hospital records and results of clinical tests	tertiary care hospital, southern Brazil: nasal swab or nasopharyngeal aspirate, or bronchoalveolar lavage collected from 755 hospitalised patients with respiratory symptoms.	2012 to 2013	season	human rhinovirus and other community acquired respiratory infections	detection of HRV was more prevalent during autumn and winter (also, reported a moderately negative correlation between viral infection frequency and temperature)

Lin J 2013	observational study using regional surveillance data	107,115 respiratory specimens of influenza-like illness outpatients were collected; Guangdong province, China	January 2004 to December 2012	season	influenza and its subtypes	Influenza activity had strong and clear seasonality with epidemic periods in summer over the 9 year period.
Montgomery AS 2020	retrospective analysis	all healthcare provider-ordered respiratory specimens from patients less than 18 years old submitted for viral testing to Tripler Army Medical Center in Oahu, Hawaii.	January 2014 to December 2018	season	influenza A/B, HPIV, RSV, adenovirus, and HMPV	RSV and influenza A showed pronounced seasonality, with peak activity from September to December and December to March, respectively. Other viruses with defined peak months were HMPV from January to May and influenza B, which oscillated above baseline from January to May; adenovirus and HPIV had a number of small peaks above baseline but demonstrated limited seasonality and year-around circulation
Moura FEA 2009	indirect immunofluorescence assay was performed on nasopharyngeal aspirates collected from children attending hospital in ambulatories, emergency rooms, and wards with suspicion of acute respiratory infection	Hospital Infantil Albert Sabin, Fortaleza, Brazil	2001 to 2007	season	influenza	influenza viruses were detected in 6.3% (234/3,708) of specimens; laboratory-based surveillance data showed a clear annual epidemic cycle of influenza, with a peak usually occurring in the rainy periods
Panayiotou C 2014	longitudinal study over 3 years, hospital based using clinical sample testing	nasopharyngeal swab samples collected from children aged <12 years, who had been hospitalized for acute respiratory tract infection in the Department of Paediatrics of Archbishop Makarios Hospital, Nicosia, Cyprus	November 2010 to March 2013	season	RSV including its genotypes	There was a clear circulation pattern from December to March in winter seasons of 2010–2011 and 2012–2013, whereas the RSV season was extended from November to April during the 2011–2012 season.
Ramaekers K 2017	observational study using clinical respiratory specimens collected during the course of hospital treatment	Patients presenting with an ARI at the University Hospitals of Leuven, Belgium; 22,876 respiratory specimens were tested for respiratory viruses,	week 30 of 2011 to week 14 of 2016	season	Influenza viruses (IAV & IBV), Human respiratory syncytial virus (hRSV), Human metapneumovirus (hMPV), Adenovirus (ADV) and Human parainfluenza virus (hPIV)	hRSV, IAV and hMPV showed, a seasonal pattern with winter peaks. hRSV followed an annual pattern with two peaks: first in young children and ±7 weeks later in elderly. hPIV and ADV occurred throughout the year with higher rates in winter
Rose EB 2018	observational study using national surveillance system data	United States of America: laboratory detections reported to the central surveillance database.	5 July 2014 to 1 July 2017	season	respiratory syncytial virus (RSV)	nationally, the median RSV onset occurred at surveillance week 41 (mid-October), and lasted 31 weeks until surveillance week 18 (early May). Median season peaks ranged from week 52 to week 7 (late December to mid-February)
Rucinski 2020	longitudinal study over 6 years of clinical samples: nasopharyngeal swabs, bronchoalveolar lavage fluid, or bronchial washings (unclear patient population)	clinical samples collected at Mayo Clinic Laboratories (Rochester, Minnesota)	1 April 2014 to 31 March 2020	season	229E, HKU1, NL63, and OC43	clinical microbiology laboratory data collected over a 6-year period illustrate seasonality of coronaviruses 229E, HKU1, NL63, and OC43, with the lowest detection rates in summer and early fall and the highest rates in winter and early spring.

Saha S 2014	observational study using international data from nasopharyngeal sample testing	Bangladesh, Cambodia, India, Indonesia, the Lao People's Democratic Republic, Malaysia, the Philippines, Singapore, Thailand and Viet Nam.	2006 to 2011	season	influenza	influenza activity peaked between June/July and October in seven countries, three of which showed a second peak in December to February; countries closer to the equator had year-round circulation without discrete peaks; viral types and subtypes varied from year to year but not across countries in a given year
Shapiro D 2017	longitudinal study over 2 years: nasal/nasopharyngeal samples were tested in duplicate using antigen-based rapid influenza testing and multiplex polymerase chain reaction (PCR) for respiratory viruses.	outpatients presenting with influenza-like illness (ILI), southern Sri Lanka	March 2013 to January 2015	season	respiratory viruses including influenza, human enterovirus /rhinovirus, respiratory syncytial virus, human metapneumovirus.	ILI and influenza showed clear seasonal variation, with peaks from March to June each year. RSV and hMPV activity peaked from May to July, whereas HEV/HRV was seen year-round
Simmerman JM 2009	active, population-based surveillance system to identify hospitalized pneumonia cases with influenza confirmed by RT-PCR or cell culture.	20 hospitals in two provinces, Thailand	Jan 2005 to Dec 2008	season	influenza among hospitalized pneumonia cases	During 2005, 2006 and 2008 influenza A virus detection among pneumonia cases peaked during June through October. In 2007 a sharp increase was observed during the months of January through April
Tan KWJ 2020	retrospective analysis of clinical respiratory samples: using standard direct immunofluorescence.	paediatric patients hospitalized with laboratory-confirmed viral respiratory tract infections in KK Women's and Children's Hospital, Singapore.	1 January 2011 to 31 December 2016	season	respiratory syncytial virus (RSV), influenza A and B viruses, parainfluenza 1, 2 and 3 viruses, metapneumovirus and adenovirus.	influenza A had two peaks, June to July and December to January; type 3 was the most common parainfluenza virus and showed annually recurring peaks; in contrast, parainfluenza 1 and 2, metapneumovirus and adenovirus had a biennial pattern; the test of seasonality detected identifiable seasonality for RSV and parainfluenza 3 virus
van der Sande 2004	observational study using hospital data surveilling respiratory infections: nasopharyngeal aspirates analysed for presence of RSV	The Gambia: all children younger than 2 years admitted with a diagnosis of acute respiratory tract infection in two referral hospitals, near the capital Banjul	1993 to 2002	rainy season	Respiratory syncytial virus (RSV)	during 1993 to 1996, epidemics occurred during the hot, rainy season; 1997 to 2000, outbreaks were not clearly related to season; 2001 and 2002, regular seasonal epidemics occurred coinciding with the hot, rainy season
Viegas M 2004	5 year retrospective analysis of nasopharyngeal aspirates	18,561 nasopharyngeal aspirates from children under 5 years of age admitted to public hospitals in Buenos Aires, Argentina with clinical diagnosis of acute lower respiratory tract infection.	January 1998 to December 2002	season	RSV, influenza A and B, parainfluenza virus (PIV), adenovirus	RSV and influenza A peaked during the coldest and dampest months, whereas PIV did so in early spring and AV lasted throughout the year; for RSV and influenza A an inverse correlation with mean monthly temperature and solar UVB radiation was detected, while it was positive when relative humidity was considered
Yang L 2009	observational study using city disease registration data; excess risks associated with influenza calculated; distributed lag non-linear models & regression tree models applied	Hong Kong, China	1996 to 2002	season	weekly numbers of mortality including influenza mortality	influenza mortality was higher in winter and late spring/early summer than other seasons; this two-peak pattern was also found for cardio-respiratory disease and sub-categories pneumonia and influenza, chronic obstructive pulmonary disease, cerebrovascular diseases and ischemic heart disease as well as for all-cause deaths
Yu J 2019	retrospective study over 8 years testing clinical samples from children with pneumonia to identify infections	4,225 hospitalized children 28 days–13 years of age with pneumonia, Beijing Children's Hospital, China	July 2007 to June 2015	season	respiratory syncytial virus (RSV)	on average the RSV season starts at calendar week 41 (mid-October) and lasts 33 weeks through week 20 of the next year (mid-May); 97% of total RSV-positive PCRs occur during this period

Table 1f. Exposure: various/multiple meteorological exposures, with or without additional variables including pollution, population size.						
Abed & Lashin 2021	observational study using international surveillance data	Italy, China and Spain	Dec 2019 to April 2020	season, air pollution (CO2 emissions), sea level, and population	numbers of COVID-19 cases	larger populations and increased air pollution were associated with higher rates of COVID-19 infection; weather temperature and mean sea level also had effects, but they were smaller than those of population and pollution
Abdelhafez E 2021	observational study using national surveillance data	Jordan	15 March to 31 August 2020	average daily temperature, maximum ambient temperature, relative humidity, wind speed, pressure, and average daily solar radiation	COVID-19 case numbers	UV radiation was negatively associated with case numbers during the first wave; in the second epidemic wave, maximum temperature and wind speed were positively associated, whilst pressure and UV radiation were negatively associated with case numbers
Abdel-Aal MAM 2022	observational study using national surveillance data	Saudi Arabia	1 March to 30 September 2020	temperature, dew point, humidity, wind speed, and pressure	daily detected COVID-19 cases	COVID-19 case numbers in most of the considered cities were significantly correlated with temperature (positive correlation) and pressure (negative correlation), but not uniformly in all cities
Aboura 2022	observational study using international surveillance data; linear regressions to analyse relationships	134 countries	1 Jan 2020 to 23 March 2021	temperature, relative humidity, precipitation, wind	incident cases, incident deaths, COVID-19	different climates are associated with different risk exposures to SARS-CoV-2; relative humidity appeared to be the most influential factor, with a strong negative relationship with COVID-19 mortality
Aboura S 2022b	observational study using national surveillance data	France	1 January 2020 to 23 March 2021	weather variables	COVID-19 cases and deaths	a rise in temperatures was negatively associated with reported deaths, while an increase in relative humidity or wind and a decrease in precipitations were negatively associated with confirmed cases; these weather variables appeared statistically significant only during the winter season
Adhikari A 2020	observational study using city surveillance data	Queens county, New York, USA	March 2020 to April 2020	ozone, PM2.5, daily meteorological variables: wind speed, temperature, relative humidity, absolute humidity, cloud percentages, and precipitation levels	COVID-19 confirmed new cases and new deaths	daily average temperature, daily maximum eight-hour ozone concentration, average relative humidity, and cloud percentages were significantly and positively associated with new confirmed cases related to COVID-19; none of these variables showed significant associations with new deaths related to COVID-19
Adnan S 2021	observational study using national surveillance data	Karachi, Lahore, and Peshawar, Pakistan	1 April 2020 to 5 June 2020	heat index (combination temperature and relative humidity) and UV index	incident COVID-19 cases	both indices show a significant positive correlation to the reproduction rate of COVID-19 cases; the minimum threshold temperature of 33 °C for heat index (with a positive variation of 3 °C to 5 °C) was significantly associated with new cases
Aggarwal 2021	observational study using national surveillance data	5 major cities, India	January to November 2020	air temperature, air pollution as indicated by [PM2.5] and [PM10]	incident COVID-19 cases	weak association of high air pollution with increased rates; no overall association for temperature
Akan AP 2022	observational study using national surveillance data	Turkey	end of November 2020 to beginning of June 2021	meteorological factors, air pollution	COVID-19-confirmed cases	O3 and PM10 from air quality parameters exhibited the strongest correlation with the number of daily cases in Kütahya and Sivas provinces; rainfall showed the strongest association with the number of daily COVID-19 cases in Denizli district

Ali Q 2021	observational study using national surveillance data	Pakistan	10 March 2020 to 4 October 2020	wind speed and air pollution	incident COVID-19 cases	the correlation between particulate matter and COVID-19 case numbers varied: positive in Pakistan, Punjab, and Islamabad Capital Territory, negative in Sindh; initially, the dose-response curve showed a positive link between wind speed and COVID-19 in Pakistan, Sindh, Khyber Pakhtunkhwa, and Islamabad Capital Territory; later, it becomes downward sloped in Sindh, Khyber Pakhtunkhwa, and Islamabad Capital Territory
Almeida 2018	retrospective observational study using national surveillance data (using first the wavelet decomposition technique to detect annual periodicity, then circular statistics to describe seasonal measures of the periodic states)	Brazil	2010 to 2016	season and latitude	Syndrome of Acute Respiratory Disease (SARI)	study found significant annual periodicity in 44% of the states; states with seasonal signature are clustered along the coast. Most Amazonian and Central West states exhibited no seasonal behavior; among the seasonal states, influenza started in Northeast region, spreading southbound
Alsayed ARM 2022	observational study using international surveillance data and applying panel data regression	Greece, Malta, Cyprus, France, Portugal, Italy, Spain	20 February 2020 to 19 February 2021	meteorological variables including temperature, precipitation, and wind speed	daily COVID-19 case numbers	average temperature, maximum temperature, and wind speed were significantly associated with COVID-19 infected cases
Álvaro-Meca A 2022a	bidirectional case-crossover study using national surveillance data; Spanish Minimum Basic Data Set (MBDS) and Spain's State Meteorological Agency.	30,445 children with ALRI under two years of age admitted to hospital.	2013 to 2015	relative humidity, temperature, NO ₂ , SO ₂ , O ₃ , PM ₁₀ , and CO	hospital admissions due to acute viral lower respiratory infections (ALRI) in children under two years	short-term exposure to climatic conditions and ambient air contaminants was linked to a higher likelihood of hospital admissions due to ALRI: lower temperature one week before hospital admission and higher relative humidity one week and two weeks before hospital admission were related to a higher odds of hospital admission; higher NO ₂ , SO ₂ , O ₃ and PM ₁₀ were each associated with increased odds of hospital admissions for viral ALRI
Álvaro-Meca A 2022b	bidirectional case-crossover study using national surveillance data; Spanish Minimum Basic Data Set (MBDS) and Spain's State Meteorological Agency	6,367 hospitalised patients over 65 years of age with viral lower respiratory tract infection (viral LRTI), Spain	2013 to 2015	temperature, relative humidity, ambient air pollutants: SO ₂ , CO, NO ₂ , O ₃ , PM ₁₀ , latitude.	viral lower respiratory tract infection (mostly identified as influenza)	low temperatures, high relative humidity, and high concentrations of NO ₂ , O ₃ , PM ₁₀ , and CO) increased the odds of hospital admissions with viral LRTI among older people
Ameh Yaro C 2022	observational study using national surveillance data	Nigeria	27 Feb to 11 Sept 2020	multiple including meteorological and population density	SARS-CoV-2 case numbers	population density, age structure, temperature and precipitation were factors that significantly influenced the transmission of SARS-CoV-2 in Nigeria
Anastasiou OE 2012	retrospective analysis of 12,763 biological samples (288 positive and 12,475 negative), including nose/throat swabs, tracheal aspirates and bronchoalveolar lavages, tested in the	Institute for Virology of the University Hospital Essen, Germany	June 2013 to December 2019	meteorological factors and seasonality	non-SARS, non-MERS coronaviruses	coronavirus infections followed a seasonal pattern, which was more pronounced in immunocompetent patients compared to immunosuppressed patients; several meteorological factors were associated with the coronavirus detection rate - when mutually adjusting for all weather factors, only temperature, relative humidity, precipitation and cloud cover contributed independently to predicting the coronavirus detection rate
Asdaq SMB 2022	observational study using national surveillance data	Saudi Arabia	September 2020 and August 2021	environmental data including average temperature, humidity, wind speed and sun exposure	COVID-19 case numbers	the data suggested that during summer condition when the weather is hot, less humid, and steady wind flow with lots of sun exposure, the COVID-19 infection rate was augmented in Saudi Arabia
Auler 2020	observational study using national surveillance data	five Brazilian cities: São Paulo, Rio de Janeiro, Brasília, Manaus and Fortaleza	13 March to 13 April 2020	temperature, humidity and rainfall	number of cumulative COVID-19 cases, new daily cases and contamination rate	higher mean temperatures and average relative humidity favored the COVID-19 transmission (not in line with reports from coldest countries or periods of time under cool temperatures)

Azizah R 2021	observational study using national surveillance data	Indonesia	1 January to 27 October 2020	climatic conditions including temperature, UV radiation, humidity; and population density	COVID-19 case numbers	there was a correlation between climatic conditions and population density with COVID-19; warmer climatic conditions (high air temperature, low rainfall, and humidity) and higher population density were associated with higher case numbers
Azuma 2020	longitudinal cohort study	28 geographical areas of Japan with documented outbreaks of COVID-19.	13 March to 6 April 2020	meteorological variables and air pollution indicators	COVID-19 case numbers	COVID-19 case numbers not significantly associated with precipitation, wind speed, relative humidity, absolute humidity, NO, NO2, O ₃ , and PM2.5. COVID-19 case numbers significantly positively associated with increase in daily temperature or sunshine hours
Babu SR 2020	observational study using national surveillance data	Delhi region, India	1 March to 30 June, 2020	weather factors and ozone	COVID-19 case numbers	temperature (maximum, minimum, average, and dew point) and wind speed exhibited a significant positive correlation with daily COVID-19 cases; diurnal temperature range, rainfall, and relative humidity showed non-significant correlations; air pollutants were found to be weakly associated with daily COVID-19 cases; O ₃ exhibited a significant positive correlation with daily COVID-19 cases in Delhi
Bagchi A 2021	observational study using national surveillance data and machine learning analyses	Delhi region, India	3rd March 2020 to 3rd July 2020	meteorological variables including wind speed, UV radiation, temperature	COVID-19 case numbers	wind speed and precipitation levels were insignificant, whereas notable associations between minimum temperature and infra-red radiative flux and case numbers
Barrón-Adame JM 2022	observational study using national surveillance data	Tambopata District, Peru	Jan 2020 to Feb 2021	meteorological variables including maximum temperature, minimum temperature, relative humidity, precipitation	number of SARS-CoV-2 infections	significant correlations between SARS-CoV-2 infections and minimum temperature; relative humidity; precipitation
Basray R 2021	observational study using national surveillance data	5 regions in Pakistan	26 February to 31 July 2020	temperature, humidity, rainfall	COVID-19 case numbers and deaths	positive correlation of COVID-19 incidence was observed with all the temperature ranges (maximum, minimum and average) and negative correlation was seen with humidity, diurnal temperature range and rainfall; COVID-19 deaths were positively associated with temperature and were negatively associated only with humidity
Batool H 2021	observational study using national surveillance data	Pakistan	10 March to 20 December 2020	weather factors including temperature, humidity, precipitation, uv radiation	COVID-19 cases and deaths	as atmospheric moisture and thermal reading declined (increase in temperature), the numbers of infected cases and death rates also declined
Ben Maatoug 2021	observational study using national surveillance data	Saudi Arabia	9 March 2020 and 19 November 2020	air pollution and meteorological parameters including difference in temperature and wind speed	COVID-19 cases	there were significantly positive associations with short-term exposure to high concentrations of PM10, NO ₂ , and O ₃ with confirmed cases of COVID-19; under certain conditions of high concentrations of PM10 associated with atmospheric stability (during the summer of 2020), SARS-CoV-2 clusters emerged
Bi 2007	observational study using national surveillance data (regression)	Beijing and Hong Kong, China	21 April to 20 May 2003	weather variables	daily new reported cases of Severe acute respiratory syndrome (SARS)	there were inverse associations between daily case numbers and maximum and/or minimum temperatures; air pressure was positively associated with daily case numbers

Bochenek B 2021	observational study using national surveillance data	Poland	April to October 2020	maximum temperature, sunshine duration, relative humidity and variability of mean daily temperature	COVID-19 case numbers	increased intertemperature and sunshine hours were associated with decreased number of confirmed COVID-19 cases; high humidity was associated with an increase in the number of COVID-19 cases 14 days later; decreased sunshine duration and increased air humidity were negatively associated with the number of COVID-19-related deaths
Boychenko S 2020	observational study using national surveillance data	Ukraine	April to August 2020	weather variables	COVID-19 case increase	inverse correlation of new cases with temperature; no increase in case rate increases over 30 °C; relative humidity of the atmosphere air and the dew point temperature were more closely related to increased transmission
Briz-Redón A 2022	observational study using national surveillance data	7 cities in Spain	2 March to 12 April 2020	meteorological variables: temperature, precipitation, wind velocity, min and max atmospheric pressure, and sunlight time; and air pollution measures	COVID-19 case numbers	no associations between either PM2.5 exposure or environmental conditions and COVID-19 transmission were found during the early spread of the pandemic
Brunelli TC 2021	observational study using national surveillance data	Mato Grosso state, Brazil	January to December 2020	temperature, humidity, wind, radiation, and precipitation	confirmed cases of COVID-19	positive correlation significant only with atmospheric pressure and fire radiative power
Burra P 2021	observational study using international surveillance data	global	Dec 2019 to April 2020	temperature, latitude	COVID-19 case numbers, mortality and recovered case numbers	temperatures were negatively correlated to incidence, mortality, recovery and active cases; latitudes were positively correlated to incidence, mortality, recovery and active cases
Caini 2018	observational study using national surveillance data	The Netherlands	1970 to 2016	meteorological factors and season	Influenza-like illness (ILI)	weekly ILI count was inversely associated ($p < 0.001$) with 0- and 1-week lagged absolute humidity and temperature. The seasonal average ILI incidence rate and absolute humidity (or temperature) were strongly (inversely) correlated
Cao H 2021	observational study using national surveillance data	5 selected regions from the north to south of China with diverse air pollution levels and weather conditions	25 January to 29 February 2020	PM2.5, PM10, SO ₂ , NO ₂ , O ₃ , and CO, temperature, relative humidity, and wind velocity	number of COVID-19 confirmed cases	higher concentrations of air pollutants and lower temperature, relative humidity and wind velocity were associated with daily new cases increasing
Cao Y 2022	observational study using international surveillance data	global	Jan to June 2020	climate, weather, population (and other factors in a multivariable model)	COVID-19 transmission rate	in a multifactorial model, climate variables only explained 1.1% of the variance in global transmission of COVID19, followed by demographic variables (0.59%)
Carleton 2021	observational study using international surveillance data	3,235 regions across 173 countries	1 Jan to 10 April 2020	UV radiation	confirmed COVID-19 cases	1 SD increase in UV was associated with lower daily growth rate of COVID-19 cases by about 1 percentage point over the subsequent 2.5 wk, relative to an average in-sample growth rate of 13.2%; the time pattern of lagged effects peaked 9 to 11 days after UV exposure, consistent with the combined timescale of incubation, testing, and reporting; cumulative effects of temperature and humidity were not statistically significant
Chadsuthi 2015	retrospective observational study using national surveillance data	2 regions in Thailand	2009 to 2014	meteorological/climate variables	suspected influenza cases	average temperature correlated with influenza cases in both central and southern regions, but average minimum relative humidity played an important role only in the southern region

Chan PKS 2015	retrospective observational study using results from testing nasopharyngeal samples	patients presented with acute respiratory illness at Prince of Wales Hospital, Hong Kong, China	15-year period (1998–2012)	season, meteorological variables (and sex, age and other variables)	incidence of influenza (Flu) A/B, respiratory syncytial virus (RSV), adenovirus (ADV), and parainfluenza viruses (PIV) 1/2/3 among hospitalized patients	a "high season," mainly contributed by flu, was observed in late-winter/early-spring (February–March); the "medium season" in spring/summer (April–August) was due to Flu and RSV; the "low season" in late autumn/winter (October–December) was due to PIV and ADV; seasonality varied between viruses, but predictable distinctive pattern for each virus existed, and temperature was the most important associating meteorological variable
Chan PWK 2002	observational study using clinical samples: nasopharyngeal samples were collected and examined for RSV by immunofluorescence, viral culture, or both	5,691 children, aged less than 24 months and hospitalized with LRTI (i.e., bronchiolitis and pneumonia), Malaysia	1982 to 1997	meteorological variables, season	RSV bronchiolitis and pneumonia	seasonal variations in RSV infection rate were evident and peaked during the months of November, December, and January.; this seasonal variation was evident for both bronchiolitis and pneumonia categories; the rate of RSV infection correlated with the monthly number of rain days and inversely with the monthly mean temperature; seasonal variations in the incidence of RSV infection was evident, with an annual peak in November, December, and January
Charland 2009	observational study using national surveillance data	35 US cities	2000 to 2005	solar radiation, dew point, temperature and geographical position	paediatric in-patient case numbers as indicator of city-specific timing of influenza outbreaks	only solar radiation was significantly related to epidemic timing
Chen B 2020	observational study using national surveillance data	China	20 January 2020 to 9 April 2020	meteorological factors	daily case rate of COVID-19	significant correlation of daily COVID-19 cases with average temperature, relative humidity, wind speed, and air visibility
Chen G 2017	observational study using national surveillance data	47 cities in China	9 September 2013 to 31 December 2014	air pollution PM2.5 and temperature	influenza daily cases	ambient PM2.5 was associated with increased case numbers of influenza in China, especially on cooler days
Chen S 2021	observational study using international surveillance data: regressed the logarithm of COVID-19 cases/million inhabitants in a country against latitude, controlling for mobility data and built environment	global	29 Dec 2019 to 9 January 2021	latitude	confirmed COVID-19 cases	a one-degree increase in absolute latitude was associated with a 4.3% increase in cases per million inhabitants
Chen Z 2013	retrospective study of hospital records and clinical samples tested for by direct immunofluorescence assay.	42,104 nasopharyngeal samples collected from children admitted to a hospital with acute respiratory infections due to seven common viruses	January 2001 and December 2011	meteorological data including temperature, humidity, rainfall	respiratory syncytial virus (RSV), influenza A and B viruses (IV-A and IV-B), parainfluenza viruses 1-3 (PIV-1, PIV-2, PIV-3), and adenovirus (ADV)	RSV and IV-A activity showed distinctive winter peak, whereas PIV-3 and ADV peaked in summer; incidence of RSV was correlated with low environmental temperature, and PIV-3 only with high temperature; IV-A activity was correlated with both low temperature and high relative humidity; ADV activity was correlated with high total rainfall; monthly number of RSV cases decreased by 11.25 % (95 % CI: 5.34 % to 16.79 %) for every 1°C increase in the average temperature
Chew FT 1998	retrospective survey of laboratory virus isolation, serology and immunofluorescence microscopy	samples with positive results, from patients admitted (or treated as outpatient) at two large general hospitals in Singapore	September 1990 to September 1994	season, meteorological factors	adenovirus, influenza viruses, para-influenza viruses, respiratory syncytial virus and rhinovirus	consistent seasonal variations in viral infections were observed only with RSV (March–August) and influenza A virus (peaks in June, December–January); the RSV trends were associated with higher environmental temperature, lower relative humidity and higher maximal day-to-day temperature variation

Chong KC 2015	observational study using city surveillance data	Hong Kong, China	2002 to 2009	meteorological variables	influenza mortality	air temperature was a common significant driver of seasonal patterns and cold temperature was associated with an increase in transmission intensity for most of the influenza epidemics; rainfall was also found to be a significant driver of seasonal influenza, although results were less robust
Chong KC 2020	observational study using national surveillance data	45 Japanese prefectures	2000 to 2018	average temperature, relative humidity, total rainfall, and actual vapour pressure, a proxy for absolute humidity, latitude	influenza-like illness as a proxy for influenza	influenza risk driven by vapour pressure was negatively correlated with latitude; low temperature and low relative humidity were predictors for influenza risk, but their risk-latitude correlations were weaker than that of absolute humidity; latitude was a mediator despite that its range in Japan is only from 26°N to 43°N
Chowell 2012	observational study using national surveillance data	Chile	1 May to 31 December 2009	population size, latitude & meteorological factors	daily hospitalizations for severe acute respiratory disease and laboratory confirmed A/H1N1 influenza infection	earlier pandemic onset was associated with larger population size; no association with connectivity, demographic, school or climatic factors; there was 16-39-day lag in disease activity from southernmost to northernmost regions; differences in latitude, maximum temperature & specific humidity explained 68.5% of the variability in peak timing
Christophi 2021	observational study using international surveillance data/ observational retrospective study	OECD countries, and states in the USA	January to April 2020	average temperature and other weather conditions measured at 25 days prior and 25 days after the first reported COVID-19 death was collected in the OECD countries and US states	cumulative COVID-19 mortality	a 1 °C increase in ambient temperature was associated with 6% lower COVID-19 mortality at 30 days following the first reported death; the results were robust for COVID-19 mortality at 25, 35 and 40 days after the first death, as well as other sensitivity analyses
Clouston 2021	observational study using local data	Suffolk County, New York state, USA	16 March to 21 Dec 2020	outdoor wind speed	daily COVID-19 incidence (as a proxy for outdoor transmission of COVID-19)	unadjusted & multivariable-adjusted analyses showed that days with temperatures between 16 and 28 °C where wind speed was < 8.85 km per hour had increased COVID-19 incidence as compared to days with average wind speed ≥ 8.85 km per hour
Correa-Araneda 2021	observational study using international surveillance data/ observational retrospective study	360 cities of Chile	23 February to 16 August 2020	mean temperature, relative humidity, atmospheric pressure, wind speed, population density	COVID-19 infection rate	transmission was greater in colder and drier cities and when atmospheric pressure was lower
Coşkun 2021	observational study using national surveillance data	81 provinces in Turkey	March 2020	temperature, humidity, number of sunny days, wind intensity	no. cases of COVID-19	wind speed (and population) positively associated with case numbers; no association for air temperature, humidity, number of sunny days, or air pollution
Dalziel 2018	observational study using national surveillance data	603 postal code areas within cities in USA	2002 to 2008	population size and density	influenza-like illness (ILI)	city-level incidence was positively correlated with population size and with spatio-temporal organization in population density
Darnette 2021	observational study using international surveillance data	37 OECD countries	1 January 2020 to 27 July 2020	temperature, humidity, solar radiation	COVID-19 cases and fatalities	temperature, humidity and solar radiation negatively associated with COVID-19 cases and fatalities; correlations with human behaviours exist and modify the associations

Del Rio 2020	observational study using international surveillance data	10 provinces in China with high number of COVID-19 cases; areas where continuous horizontal transmission outside of China was reported; areas where imported cases were detected & no horizontal transmission was documented after 7+ days since first case	31 December 2019 to 29 February 2020	temperature, rainfall	SARS-CoV-2 transmission rates	regions without ongoing human-to-human transmission had significantly higher temperatures compared to China & countries with ongoing human-to-human transmission, with over 11-degree difference; average rainfall during the study period was significantly higher in regions without ongoing transmission when compared to the Chinese provinces with ongoing human-to-human transmission and other regions with active transmission of SARS-CoV-2
Deyle ER 2016	observational data using global surveillance data: laboratory confirmed influenza A and B cases/week retrieved on 2 April 2014 from World Health Organization via FluNet	global	1 January 1996 to 26 March 2014	temperature, humidity, precipitation, season	laboratory confirmed influenza A and B	nonlinear analysis show a U-shaped effect of absolute humidity on influenza, and also that temperature mediates this relationship
Diouf I 2022	observational study using national surveillance data	16 countries in three climatic regions of Africa: Sahel, Maghreb, and Gulf of Guinea	1 March to 30 November 2020	surface air temperature specific humidity and water vapor	COVID-19 cases	statistically significant inverse correlations between COVID-19 cases and temperature over the Maghreb and the Gulf of Guinea regions; in contrast, positive correlations in the Sahel area, especially in the central part, including Niger and Mali; correlations with specific humidity and water vapour parameters significant and positive in Sahelian and Gulf of Guinea countries and negative in Maghreb countries
Dragone R 2021	observational study using national surveillance data	Lombardy region, Italy	February to March 2020	sulphur dioxide, ammonia, nitrogen dioxide, nitrogen monoxide, carbon monoxide, ozone, and suspended particulate matter measuring less than 10 µm (PM10) and less than 2.5 µm (PM2.5); temperature, humidity, wind speed	COVID-19 infection cases	positive correlation between spatial distribution of COVID-19 infection cases with high concentrations of suspended particulate matter and a negative relationship with ozone
Du M 2022	observational study using regional surveillance data	Lanzhou, China	2014 to 2017	meteorological factors including pressure, temperature, rainfall, humidity, hours of sunshine, wind speed; season	influenza case numbers	case numbers peaked in winter, with a secondary peak in spring, and a trough in summer and autumn; influenza cases in Lanzhou increased with increasing daily pressure, decreasing precipitation, average relative humidity, hours of sunshine, average daily temperature and average daily wind speed; low temperature appeared to be important for the increase of transmission intensity of seasonal influenza
Ebi 2001	observational study using hospital data	women, California, USA	January 1983 through June 1998	weather variables	hospitalization for viral pneumonia	associations varied by region: hospitalizations in San Francisco & Los Angeles increased significantly with decreased minimum temperature; hospitalizations in Sacramento increased significantly with decreased maximum temperature difference; these associations were independent of season; El Niño events were associated with hospitalizations only in Sacramento, with significant decreases for girls and increases for women

Emediegwu LE 2021	observational study using national surveillance data; econometric approach	all counties in the continental US	21 January to 31 October 2020	climatological variables	COVID-19 case increase rate	increased daily temperature or relative humidity was associated with reduced daily COVID-19 growth rate; increased daily wind speed was associated with reduced daily growth rate of COVID-19
Endeshaw FB 2022	observational study using national surveillance data	Addis Ababa, Ethiopia	10 March 2020 to 31 October 2021	climatic factors including temperature, rainfall, relative humidity, sunshine duration, and wind speed	number of daily COVID-19 cases	a significant correlation between COVID-19 cases and humidity was observed; the highest increase in the effect of wind speed and rainfall on COVID-19 was observed at 14 lag days prior to detection; daily average temperature and sunshine duration were not significantly linked with COVID-19 risk across the full lag period
Fadli A 2020	observational study using national surveillance data	Surabaya, Indonesia	1 June to 1 July 2020	temperature, humidity, hours of sunlight	COVID-19 cases	the weather was associated with the number of COVID-19 patients; the highest order of correlation were the average duration of sunlight, the average temperature and the average humidity
Faruk MO 2022	observational study using international surveillance data	45 countries globally	1 March 2020 to 19 July 2021	relative humidity, temperature, sky clearness, and wind speed	COVID-19 cases	relative humidity, temperature, sky clearness, and wind speed were associated with increased case numbers of COVID-19; the spread of COVID-19 infection and death was highest at low temperatures
Fawad 2021	observational study using national surveillance data	Pakistan	March to June 2020	daily average temperature, daily average dew point, daily average humidity, daily average wind speed, daily average pressure	incidence of COVID-19	temperature and dew point had a positive linear relationship with daily infected cases of COVID-19
Fernández D 2021	observational study using international surveillance data	global	21 January to 18 May 2020	national biodiversity index, air quality & pollutants (PM10, PM2.5, and O3), temperature, and precipitation	COVID-19 case numbers and deaths.	statistically meaningful association between COVID-19 infection national biodiversity index, air quality, and pollutants elements; particularly, there was a significant relationship of loss of biodiversity, high level of air pollutants, and diminished air quality with COVID-19 infection spread and mortality
Flight WG 2014	prospective study over 1 years: sputum, nose and throat swabs taken every 2 months and additionally at onset of pulmonary exacerbations or upper respiratory tract infection; PCR used to test for 9 viruses; hourly temperature and relative humidity measurements were recorded throughout the study	98 adults with cystic fibrosis, Manchester, UK, followed for 12 months	22 December 2010 and April 2012	temperature, humidity, vapour pressure, season	adenovirus, influenza A&B, human metapneumovirus, parainfluenza 1–3, respiratory syncytial virus (RSV) and human rhinovirus	when all viruses were considered together, the incidence appeared fairly constant throughout the year; however, when considered in groups of rhinoviruses vs non-rhinoviruses, clear pattern of rhinovirus peaks in summer and autumn months; non-rhinovirus viral respiratory infection was most common during the winter and spring with very low levels of activity during the summer; risk of rhinovirus increased as the ambient temperature increased and vapour pressure increased; negative association of rhinovirus with relative humidity; non-rhinovirus viral respiratory infections showed a strong negative association with ambient temperature and vapour pressure but a positive association with relative humidity over the previous week
Fronza 2020	observational study using national surveillance data	47 regional capitals of Europe, and 107 major Italian cities,	10 February to 10 April 2020	air pollution, dewpoint temperature, wind speed	SARS-CoV-2 infection cases	SARS-CoV-2 infection frequency positively correlated with particulate air pollutants, and specifically with particulate matter 2.5, while ozone gas was negatively related with the number of infected individuals

Gardner 2019	case crossover study to identify meteorological factors that may increase the risk of primary MERS infections in humans	Saudi Arabia (n=1,191); each case's exposure status on individual days before disease onset (the exposure window) was compared to the exposure status on different days during a control period	January 2015 – December 2017	meteorological variables: daily mean, minimum, and maximum temperature, relative humidity, wind speed, and visibility	Middle East Respiratory Syndrome Coronavirus (MERS-CoV)	lowest temperature and humidity were associated with increased cases 8 to 10 days later; high visibility was associated with increased number of cases 7 days later; wind speed also statistically significant associated with cases 5 to 6 days later
Gomez-Barroso 2017	observational study using national surveillance data	Spain	five influenza seasons: 2010–2011 through to 2014–2015	meteorological variables	influenza-like illness (ILI) rates	associations were observed between ILI rates and dew point and cumulative precipitation: higher dew point temperature was associated with reduced ILI rates; increased weekly rainfall was associated with increased ILI rates
Gómez-Herrera S 2021	observational study using national surveillance data; rank correlation tests and a neural network named self-organising map.	Colombia	25 March 2020 15 January 2021	daily average temperature, minimum temperature, maximum temperature, relative humidity, absolute humidity, specific enthalpy and wind speed	COVID-19 case numbers	meteorological variables had heterogeneous associations with case numbers across different biogeographical regions: wind speed was one of the factors connected with the highest contamination rate recorded in Leticia; highest new daily cases were recorded in Bogota where cold/dry conditions (average temperature <14 °C and absolute humidity >9 g/m3) appeared to favour the infection rate; in contrast, Barranquilla, Cartagena and Leticia presented an opposite trend, especially with the absolute humidity >22 g/m3
Gupta A 2020	observational study using national surveillance data	9 major cities, India	1 March to 4 June 2020	daily maximum, minimum, mean and dew point temperature, wind speed, relative humidity, and diurnal range in temperature and relative humidity	COVID-19 infections	there were no clear linear correlations between individual weather parameters and coronavirus case numbers; there was some evidence that transmission was related to certain weather patterns
Gurgel RQ 2016	longitudinal study over 1 year: nasopharyngeal aspirates collected and analyzed	507 children, aged up to 24 months and hospitalized with LRTI in one of the participating centers: Aracajú, Salvador, Recife, and Maceió, Brazil	April 2012 to March 2013	average monthly temperature (°C), relative humidity (%), solar radiation (kJ/m2), and precipitation (mm); season	RSV, influenza, parainfluenza, adenovirus, rhinovirus, metapneumovirus, bocavirus, and coronavirus	frequency of viral infections was associated with increasing temperature and decreasing humidity
Habeebullah TM 2021	observational study using national surveillance data	Saudi Arabia	March to October 2020	meteorological factors	daily confirmed COVID-19 cases	highest daily COVID-19 cases in Makkah and Madinah were reported during the hottest months of the year (April to July 2020) when outdoor temperature ranged from 26.51 to 40.71 °C in Makkah and of 23.89 to 41.20 °C in Madinah; partial negative correlation was detected between outdoor relative humidity and daily recorded COVID-19 cases; there was no clear correlation between wind speed and daily COVID-19 cases
Hachim 2021	retrospective cohort study (meteorological data obtained retrospectively)	434 COVID-19 patients admitted to hospital in Dubai, UAE	Jan to June 2020	temperature, solar radiation, humidity, within a hot geographical region	clinical (and laboratory) outcomes in COVID-19 patients	admission on days with higher temperatures, higher solar radiation, and less humidity was associated with higher number of deaths
Han F 2022	observational study using national surveillance data	China	Dec 2019 to 8 April 2020	meteorological factors, air pollution	cumulative confirmed cases of COVID-19	meteorological factors and pollutant factors could only explain the difference of 1% in the COVID-19 incidence rates; the influence of meteorological factors was stronger than that of air pollution factors, and the interactive effects between factors were stronger than their individual effects

Han Y 2022	observational study using international surveillance data	188 countries	March to November 2020	temperature, rainfall, wind speed, relative humidity, air pressure, air pollutants nitrogen dioxide, sulfur dioxide, carbon monoxide, ozone (and socioeconomic aspects)	new confirmed cases of COVID-19 per 100,000 people	global new confirmed cases of COVID-19 per 100,000 people were negatively correlated with temperature, relative humidity, rainfall, wind speed, air pressure, and positively correlated with air pollutants (NO ₂ , SO ₂ , O ₃) and socioeconomic aspects; the interaction of SO ₂ and O ₃ , SO ₂ and relative humidity, and O ₃ and temperature strongly associated with incidence rate; associations were non-linear, with one or more inflexion points
Hariharan R 2021	observational study using national surveillance data	Delhi, India	April to July 2020	meteorological parameters including daily mean temperature, absolute humidity and average wind speed	COVID-19 case number increases	absolute humidity, temperature and wind speed were weakly positively associated with increased case numbers of COVID-19 infection
He M 2022	observational study using global surveillance data	global	29 Dec 2019 to 1 Sept 2020	air temperature at the height of 2 m above the surface (land, sea, or inland waters), precipitation, relative humidity, wind speed at the height of 10 m, downward UV radiation flux at the surface (UV, in the range of 250–440 nm), and diurnal temperature range	daily growth rate of COVID-19 case numbers	the case number daily growth rate was significantly correlated with the ultraviolet flux and temperature, but not with precipitation, humidity, and wind
Heibati 2021	time-series analysis	Finland: overall and within the 21 hospital districts	1 Jan to 31 May 2020	meteorological and pollution factors: temperature, relative humidity; PM10; nitrogen dioxide NO ₂	incidence of COVID-19	no associations between daily temperature and incidence rate of COVID-19; daily average relative humidity was negatively associated with daily incidence rate of COVID-19 in two hospital districts located inland; no such association was found nationwide
Hochman A 2021	observational study using surveillance data across three countries	Israel, Palestine, Jordan	2004 to 2017	winter low-pressure weather regime: Cyprus Lows	influenza incidence	Cyprus Lows weather events were significantly correlated with influenza in Israel, the Palestinian Authority and Jordan; the occurrence of Cyprus Lows preceded the onset/maximum of influenza incidence by 1 to 2 weeks and followed their timing
Hossain S 2021	observational study using international surveillance data	Afghanistan, Bangladesh, India, Pakistan, and Sri Lanka	29 Dec 2019 to 31 August 2020	Rainfall, relative humidity, maximum and minimum temperature, surface pressure, maximum air pollutants matter PM 2.5 and maximum wind speed	daily confirmed cases of COVID-19	maximum wind speed were significantly negatively associated with COVID-19 case numbers in India and Sri Lanka; associations with temperature and rainfall were variable positive and negative; maximum air pollutants matter PM 2.5 was negatively associated with the confirmed cases of COVID-19
Hridoy A-E A 2021	observational study using national surveillance data	Bangladesh	5 April to 20 September 2020	mean temperature, relative humidity, precipitation, and wind speed	COVID-19 incidence rate	mean temperature, relative humidity, and wind speed were substantially associated with an increased COVID-19 incidence rate; daily precipitation was significantly associated with a decreased risk of COVID-19 incidence rate
Hu W 2012	observational study using national surveillance data	Brisbane, Australia	2009	maximum temperature, weekly rainfall	influenza A (H1N1)	average increase in weekly H1N1 cases were associated with decreased average weekly maximum temperature at a lag of one week; and a 10mm decrease in average weekly rainfall at a lag of one week; an interactive association between temperature and rainfall on H1N1 incidence was found

Hu W 2015	observational study using regional surveillance data	Shanghai, China	19 February to 14 April 2013	meteorological variables including temperature and rainfall	confirmed H7N9 infection cases	H7N9 incidence rate was significantly associated with fortnightly mean temperature and fortnightly mean rainfall
Huang X 2017	observational study using state level surveillance data	Queensland, Australia	1 January 2010 to 31 December 2012.	monthly minimum temperature, monthly vapor pressure, school calendar pattern, socioeconomic status	incident influenza cases	increased temperature was associated with decreased case numbers; increased vapor pressure was associated with increased case numbers; associations were stronger in younger (0 to 14 yrs) age groups compared with older (≥ 65 yrs) age groups
Huang X 2021	observational study using national surveillance data	Hubei province, China	23 January 2020 to 8 April 2020	ground temperature, precipitation, atmospheric pressure, relative humidity, sunshine duration, temperature, and wind speed	COVID-19 case numbers	results suggest that associations of environmental and meteorological factors with COVID-19 case numbers were not statistically significant
Hughes VC 2020	observational study using national surveillance data	50 cities in the US	1 to 30 April 2020	temperature, dewpoint and population density	COVID-19 case numbers	population density was significantly associated with the number of COVID-19 cases in April 2020; while both temperature and dewpoint resulted in a negative correlation in association with COVID-19 cases, those associations were not statistically significant
Imran A 2021	observational study using national surveillance data	Bangladesh	March to September 2020	meteorological data include daily average temperature, humidity, and wind speed,	COVID-19 case numbers, case fatality rate, recovery rate	all the studied meteorological parameters were positively correlated with the daily new cases and deaths in Bangladesh, while the highest correlations were observed for the 14 days incubation period
Ince N 2020	observational study using national surveillance data; preliminary study on 197 cases	Turkey	29 March 2020 to 4 May 2020	meteorological factors and air pollution	COVID-19 case numbers	significant negative correlation between case numbers and air temperature, relative humidity, and NO ₂ , and significant positive correlation with air pressure, but no correlation with PM ₁₀ , PM _{2.5} , SO ₂ , NO, or CO
Ishii 2021	observational study using international surveillance data	Sendai City, Japan	July 2020 to April 2021	natural environmental factors	weekly number of newly diagnosed COVID-19 cases	weekly test positive rate correlated with lower air humidity and higher wind speed
Islam ARMT 2021	observational study using national surveillance data	8 divisions of Bangladesh	March to April 2020	meteorological factors	COVID-19 cases and deaths	every 1 mm increase in rainfall was associated with elevated COVID-19 case numbers; increase in diurnal temperature was associated with reduced confirmed cases; humidity was associated with increased cases
Islam ARMT 2020	observational study using national surveillance data	Bangladesh	8 March to 31 May 2020	meteorological factors including minimum and mean temperature, wind speed, relative humidity and absolute humidity	COVID-19 confirmed cases	minimum and mean temperature, wind speed, relative humidity and absolute humidity had a significant positive correlation with the number of COVID-19 confirmed cases
Islam N 2021	observational study using international surveillance data	Global (206 countries/regions)	Dec 2019 to 20 April 2020	meteorological factors including wind speed, cloud cover, temperature, humidity	COVID-19 cases	there was association between COVID-19 cases and 7-day-lagged temperature, relative humidity, UV index, and wind speed, after adjusting for potential confounders, but a positive association with 14-day-lagged temperature and a negative association with 14-day-lagged wind speed; higher was associated with higher rate of COVID-19 cases, although above >10 g/m ³ there was not a significant association; these findings were robust in the 14-day-lagged analysis
Ismail IMI 2022	observational study using national surveillance data	6 cities, Saudi Arabia	1 March to 31 August 2020	meteorological (temperature, relative humidity, and dew) and air quality indicators (PM ₁₀ , CO, and SO ₂)	daily COVID-19 infections and deaths	temperature, humidity and air pollution indicators were related nonlinearly with cases and deaths

Jackson 2021	retrospective cohort study	Seattle, USA	3 Feb to 15 Feb 2019	weather-related social distancing (due to severe snowfall)	incidence rates of respiratory viruses treated in acute hospitals in Seattle	disruption in contact patterns associated with the severe snowfall was associated with reduced incidence of respiratory virus hospital admission; incidence reductions were greatest for viruses that were peaking when the disruption occurred and least for viruses in an early epidemic phase
Jansson MK 2022	case-crossover study (time-stratified)	5 US study sites New York City; Marion County, Indiana; Baltimore and Baltimore County, Maryland; Franklin County, Ohio; King County, Washington.	Date of first COVID-19 cases reported on consecutive days to 1 May 2021	temperature, humidity, precipitation, cloud cover	COVID-19 infection	higher-than-average temperatures were consistently associated with a decreased relative risk of COVID-19 infection in four study sites; higher-than-average humidity levels were associated with an increased relative risk of COVID-19 infection in four study sites
Jamshidi S 2020	observational study using international surveillance data	Global and regional data	1 January to 15 August 2020	weather, adjusting for consideration of urban density, mobility, homestay, demographic information, and mask use within communities.	COVID-19 cases	on global to regional scales, there were heterogeneous relationships between weather and new case numbers (these associations were confounded by decentralized policies, weather variability, and the onset of screening for COVID-19); weather alone was identified as a factor with a possible impact of >3%
Jüni 2020	longitudinal study over 14 days (of regions, not individuals)	all 144 geopolitical areas worldwide (375 609 cases) with at least 10 COVID-19 cases and local transmission by 20 March 2020, excluding China, South Korea, Iran and Italy	7 March to 20 March 2020	latitude, temperature, humidity (also public health interventions)	epidemic growth (expressed as ratios of rate ratios comparing cumulative counts of COVID-19 cases on 27 March 2020 with cumulative counts on 20 March 2020)	no associations of epidemic growth with latitude and temperature, but weak negative associations with relative humidity and absolute humidity.
Jusot J-F 2012	observational study using nasopharyngeal swab collection and testing by RT-PCR	Niamey, Niger	2009 to 2010	temperature, visibility	influenza A and B (as confirmed by RT-PCR)	influenza cases increased significantly with minimal temperatures and high visibility
Kante IK 2021	observational study using regional surveillance data	Conakry, Republic of Guinea	1 March to 31 May 2020	temperature, humidity, diurnal temperature	COVID-19 number of cases and deaths	increased temperature was linked to a decline in the COVID-19 number of cases and deaths, while increased humidity was positively correlated with number of cases and deaths; low temperature, mild diurnal temperature and high humidity appear to favour transmission of SARS-CoV-2
Kaplin A 2021	observational study using international surveillance data	50 Northern Hemisphere countries with sufficient COVID-19 case and meteorological data for analysis	22 January 2020 to 6 April 2020	meteorological factors and season	COVID-19 case numbers	temperature was correlated with rate of increase in COVID-19
Kamigaki T 2016	observational study using international surveillance data; nasopharyngeal samples were collected from patients with influenza-like illness and analysed	Eastern Visayas region and Baguio City in the Philippines, and Okinawa Prefecture in Japan	January 2010 to December 2012	temperature, relative and specific humidity, precipitation, and number of rainy days	influenza and respiratory syncytial virus	at all three study sites, annual seasonal peaks were observed in influenza A and RSV; peaks were unclear for influenza B
Karapiperis C 2021	observational study using international surveillance data	Canada, Australia, Japan, South Africa, Austria, New Zealand, Norway, Chile, Greece, Ireland	1 January 2020 to 30 November 2020	season, UV radiation	COVID-19 daily incidence rates	UV radiation was strongly associated with incidence rates, indicating that UV is a key seasonality indicator for COVID-19
Karimi SM 2021	observational study using national surveillance data	USA	29 Dec 2019 to 30 June 2020	minimum and maximum daily temperature, precipitation, ozone concentration, PM2.5 concentrations, and UV light index.	COVID-19 deaths	increased minimum temperature was associated with increased deaths 20 days later; an ozone concentration increase was associated with decreased daily deaths by ; ozone levels below 38 parts per billion were negatively correlated with deaths

Karmokar J 2022	observational study using national surveillance data	Pakistan	8 March 2020 to 31 January 2022	11 meteorological parameters	COVID-19 cases and deaths	cloud cover was strongly positively associated with COVID-19 cases; minimum temperature was positively associated with deaths; wind speed was strongly negatively associated with all COVID-19 parameters, air quality was negatively associated deaths, air pressure was weakly negatively associated daily cases and death, and rain was weakly negatively associated with daily cases
Kato M 2022	cross-sectional study using national surveillance data	Japan	15 January to 17 March 2020	meteorological factors including as air temperature, humidity, and sunlight exposure	COVID-19 incidence rate ratio	higher values of air temperature, relative humidity and sunlight exposure were associated with lower incidence of COVID-19
Keetels GH 2022	observational study using national surveillance data	The Netherlands	1995 and 2019 for influenza, January 2020 to May 2022 for SARS-CoV-2	dew point temperature (calculated from temperature and humidity data)	influenza, and SARS-CoV-2	for influenza and SARS-CoV-2, a significant correlation was found between the dew point temperature and case numbers and/or mortality indices
Khalis M 2022	observational study using regional surveillance data	Casablanca region, Morocco	2 March 2020 to 31 December 2020	meteorological parameters, air quality: CO, NO ₂ , O ₃ , SO ₂ , PM ₁₀	daily confirmed COVID-19 cases	positive associations were observed between COVID-19 and wind above 20 m/s and humidity above 80%; temperatures above 25° were negatively associated with daily cases of COVID-19; PM ₁₀ and O ₃ had a positive association with the increase in the number of daily confirmed COVID-19 cases, while precipitation had a borderline effect below 25 mm and a negative association above this value
Khor C-S 2012	retrospective observational study using national surveillance data	10,269 respiratory samples from all children (≤ 5 years old) admitted with respiratory tract infection in a tertiary hospital, Kuala Lumpur, Malaysia	1982 to 2008	season, rain days, relative humidity, temperature	respiratory syncytial virus (RSV), influenza A and B, parainfluenza types 1-3, and adenovirus	the four main viruses caused disease throughout the year, with a seasonal peak observed for RSV in September to December; monthly RSV cases were directly correlated with rain days, and inversely correlated with relative humidity and temperature
Kolluru SSR 2021	observational study using national surveillance data	5 cities, India	February 2020, May 2020, June 2020	air quality index, PM _{2.5} , PM ₁₀ and CO; ground level ozone (O ₃); temperature, relative humidity, wind speed	COVID-19 confirmed cases and deaths	the results showed significant correlation of PM _{2.5} , PM ₁₀ , CO, O ₃ concentrations, air quality index and meteorological parameters with the confirmed cases and deaths during the lockdown period; among the meteorological variables considered, temperature strongly correlated with the COVID-19 cases and deaths
Kulkarni H 2021	observational study using national surveillance data	India	1 March to 31 May 2020	air temperature, relative humidity, air pressure, wind speed and rainfall	reproduction rate estimated from daily COVID-19 case counts	mean daily air temperature was inversely significantly associated with time dependent case number reproduction rate; wind speed was significantly positively associated with case number reproduction rate
Kumar G 2020	observational study using national surveillance data	Mumbai, India	27 April to 25 July 2020 (90 days)	meteorological factors	daily case rate of COVID-19	a significant correlation of COVID-19 was found with temperature, dew point, relative humidity and surface pressure
Kumar S 2020	observational study using national surveillance data	India	1 March to 31 May 2020	meteorological factors	daily cases of COVID-19	the study found a positive association between daily COVID-19 cases and temperature and a mixed association with relative and absolute humidity in India
Kuo T-C 2020	observational study using national surveillance data	Lima, Peru	7 March to 10 May 2020	weather variables and pollution	daily cases of COVID-19	there was a significant association between ambient temperature and PM ₁₀ and COVID-19 cases, while no significant correlation was observed with PM _{2.5}
Landier 2021	observational study using international surveillance data	63 regions in USA, Portugal, Canada, Spain, Italy, France	not reported, but publication was 2021	weather and climatic variables	SARS-CoV-2 reproduction number as estimated from death counts	colder and less humid weather was associated with more rapid spread, after adjusting for population density and other factors

Laohavichien P 2022	observational study using international surveillance data, looking at correlations and clustering of data	global	Dec 2019 to May 2021	temperature, relative humidity, wind speed	daily number of confirmed cases of COVID-19:	these three weather conditions were all associated with the COVID-19 confirmed cases: there was a negative relationship between temperature and the number of new cases, with positive relationships with the conditions of relative humidity and wind speed
Lau 2018	observational study using local surveillance data	11 sub-provincial prefecture cities in Zhejiang, China	13 March 2013 to 30 June 2016	total rainfall, average wind speed, average temperature, average relative humidity, and sunshine duration	avian influenza A H7N9 virus	meteorological factors showed lagged & nonlinear effects on human H7N9 infection. Wind speed & rainfall were significant independent factors. Rainfall between 60.3 and 200.3 mm favoured human H7N9 infection. Wind speed of 2.1–3.0 m/s & 6.3–7.1 m/s favoured human H7N9 infection.
Ledebur K 2022	observational study using international surveillance data	Austria	1 July 2020 to 15 May 2021	meteorological variables	COVID-19 case numbers	decreasing temperature and humidity, increasing cloudiness, precipitation and the absence of mitigation measures for public events were the factors most strongly associated with increased virus transmission, together being associated with a doubling of the transmission rates compared to regions with more favourable weather
Lestari S 2021	observational study using national surveillance data	Malaysia	June 2020 until December 2020	weather variables including temperature and precipitation	COVID-19 case numbers	lack of evidence for a relationship between weather factors and COVID-19 cases
Li H 2020	retrospective observational study using national surveillance data	Wuhan and XiaoGan, China	26 Jan to 29 Feb 2020	air quality index, ambient air pollutants (PM2.5, PM10, NO2 and CO), meteorological variables: daily temperature, highest temperature, lowest temperature, temperature difference & sunshine duration	COVID-19 incidence	air quality index, PM2.5, NO2, and temperature were all positively correlated with COVID-19 incidence
Li Y 2020	observational study using national disease registry data	paediatric patients aged 0 to 18 years treated at Shanghai Children's Medical Centre	1 July 2017 to 30 June 2019	temperature, relative humidity, pollution	paediatric influenza A and B	high PM1, low and high temperatures were significantly associated with the number of influenza A cases; low temperature and high PM1 were significantly associated with the number of influenza B cases.
Lim YK 2021	observational study using national surveillance data	Seoul metropolitan region and Daegu-Gyeongbuk region, Republic of Korea	February 2020 to July 2020	environmental data including temperature, sunshine hours/day, ozone level	COVID-19 cases	duration of sunshine and ozone level were found to positively correlate with COVID-19 cases in both regions; however, the association of temperature variables with COVID-19 transmission revealed contradictory results when comparing the data from the two regions in Korea
Lin C 2020	observational study using national surveillance data	16 provinces in China with altitude <500m	22 January to 29 February 2020	meteorological variables and population density	COVID-19 newly confirmed cases	population density had a non-linear relationship with disease spread; among various meteorological factors, only temperature was significantly negatively associated with rate of increase of case numbers after controlling for the effect of population density
Lin G 2022	observational study using national surveillance data	USA	2020 to 2021	absolute humidity and human mobility in different climatological regimes	reported cases of COVID-19	increasing humidity was associated with declining cases; decreasing humidity and increase in residential mobility during winter months was associated with increases in COVID-19 cases; the effects of humidity were generally greater in regions with lower humidity levels

Lin J 2020	observational study using national surveillance data	China, Hong Kong, and Singapore	1 to 30 April 2020	meteorological factors (and control strategies)	COVID-19 confirmed cases	high temperature was associated with lower case number increases; high relative humidity was associated with higher COVID-19 transmission when temperature was low, but tended to be associated with reduced transmission when temperature was high
Lin S 2020	observational study using national surveillance data	China	21 Jan 2020 and 3 Apr 2020	meteorological factors and air pollution	COVID-19 confirmed cases, to give an estimated case number reproduction number	CO was positively while NO ₂ was inversely correlated with case number reproduction number; daily maximal temperature, wind speed and air pressure were inversely correlated with case number reproduction number; correlations varied by region
Liu J 2020	observational study using national surveillance data	30 provincial capital cities of China	20 January to 2 March 2020	ambient temperature, diurnal temperature range, absolute humidity and migration scale index	COVID-19 confirmed case counts	meteorological factors appeared to play an independent role in the COVID-19 transmission after controlling for population migration; local weather conditions with low temperature, mild diurnal temperature range and low humidity probably were associated with greater transmission
Lin R 2022	observational study using national surveillance data	China	1 Jan to 19 Feb 2020	weather (also urban factors, non-pharmaceutical interventions adjusted for)	COVID-19 confirmed cases growth rate	higher mean temperature was associated with a slight increase in confirmed cases growth rate when mean temperature was above -7 °C; when the relative humidity was greater than 46%, it was negatively correlated with the rate of confirmed cases; the association with temperature was strongest in the east, the association of relative humidity was strongest in the central region, and the association with weather conditions was stronger in coastal regions; rising diurnal temperatures reduced the negative associations of weather conditions on the spread of COVID-19
Lin S 2022	observational study using national surveillance data	30 provinces and cities, China	10 Jan to 26 Feb 2020	wind speed, humidity, temperature, precipitation	transmissibility, incidence rate, and the number of reported cases of COVID-19	precipitation and wind speed were negatively associated, and humidity was positively associated, with the number of reported cases; higher temperature was associated with lower rate of case number increase; there was a lag in the association between temperature and case rates, while the remaining five meteorological factors had immediate and lag effects on the incidence rate and the number of reported cases
Li X 2021	observational study using international surveillance data to analyze correlations	global	up to 31 December 2020	meteorological factors, air quality, season, latitude	COVID-19 cases	the cold season in the Southern Hemisphere countries was associated with increased infections, the warm season in the Northern Hemisphere countries was associated with a reduction in case numbers; COVID-19 seasonality was more pronounced at higher latitudes, where larger seasonal amplitudes of environmental indicators were observed
Liu Z 2021	observational study using international surveillance data to analyze correlations	Moscow, Russia; Lima, Peru; Kuwait; Singapore	20 March 20 to 30 September 2020	daily average temperature, wind speed, dew point, and other weather factors	daily new COVID-19 cases	daily cases in Moscow, Lima, and Singapore were all negatively correlated with absolute humidity, while in Kuwait, daily-cases were associated with relative humidity

Lin H-C 2009	observational study; time series analysis approach to assess an eight-year nationwide population database.	477,541 pneumonia patients, Taiwan	1 Jan 1998 to 31 Dec 2005	ambient temperature, relative humidity, atmospheric pressure, rainfall, and total hours of sunshine	community-acquired pneumonia (viral vs bacterial not specified)	spring occurs in Taiwan from March to May, summer from June to August, autumn from September to November, and winter from December to February; hospitalizations were most numerous between January through April, sharply decreased in May, and were least numerous between August through October; then, an upward trend started in November and peaked again in January; community acquired pneumonia hospital admissions were also associated with ambient temperature
Lin S 2020	observational study using international surveillance data	65 countries with > 10,000 confirmed COVID-19 cases	22 March to 22 June 2020	average monthly high temperature, average monthly low temperature, sea level pressure, altitude, wind speed, rainfall, dew point temperature and relative humidity	daily new COVID-19 cases	in countries with more than 10,000 confirmed cases worldwide, moderate to high correlations between number of newly diagnosed cases per day and temperature and relative humidity
Lolli 2020	observational study using national surveillance data	in two large metropolitan areas in Northern Italy as Milan and Florence and in the autonomous province of Trento	8 March 2020 to 19 June 2020	meteorological variables and air pollution indicators	COVID-19 cases	temperature and humidity related variables were negatively correlated with COVID-19 cases; air pollution (PM2.5) showed a weaker positive correlation
Lym Y 2022	observational study using national surveillance data	Seoul, South Korea	1 August to 31 December 2020	air pollutants and temperature	daily confirmed cases of COVID-19	there was a positive correlation between a 7-day lagged effect of PM2.5 concentration and the number of confirmed COVID-19 cases; temperature had a negative correlation with the number of COVID-19 cases
Ma Y 2021	observational study using national surveillance data	2,669 counties in the USA	15 March to 31 December 2020	temperature, humidity, UV	SARS-CoV-2 transmission as indicated by an estimated reproduction number	lower air temperature (within the 20 to 40 °C range), lower specific humidity, and lower ultraviolet radiation were significantly associated with increased case number reproduction number; cold and dry weather and low levels of ultraviolet radiation were moderately associated with increased SARS-CoV-2 transmission, with humidity playing the largest role
Mahamat 2013	longitudinal surveillance study; GPs collected nasopharyngeal swabs for influenza-like-illness symptomatic patients	French Guiana	January 2006 to December 2010	daily data on rainfall (RF), temperature and relative humidity; season	influenza strains type and rate circulating	increased rainfall and low levels of specific humidity were associated with influenza transmission
Mangla S 2021	observational study using national surveillance data	Delhi, India	14 Mar 2020 to 3 May 2021	PM2.5, PM10, CO, NO, NO2, and O3 and meteorological parameters (temperature, humidity, wind speed, and rainfall)	COVID-19 cases and deaths	there was a significant correlation between COVID-19 incidences and PM2.5, PM10, CO, NO, NO2, and O3 concentrations; amongst the four meteorological parameters, temperature was strongly correlated with COVID-19 infections and death
Martins LD 2020	observational study using national surveillance data	5 states in Brazil to represent tropical and subtropical regions	2017-2019 for influenza hospitalizations; 1 March to 15 May 2020 for COVID-19.	meteorological variables	influenza hospitalizations and COVID-19 cases and deaths	temperature combined with humidity were risk factors for COVID-19 and Influenza in both climate regimes, and the minimum temperature was also a risk factor within subtropical climate regions
Mattiucci C 2021	observational study using national surveillance data	Verona, Italy	1 March to 11 November 2020	meteorological variables	new daily cases of COVID-19	the number of daily COVID-19 diagnoses in Verona was positively associated with the number of days in lockdown and humidity, and inversely correlated with mean, minimum and maximum temperature, mean wind speed and number of days with rainfall

Metelmann S 2021	observational study using national surveillance data	374 large cities globally	Dec 2019 to June 2020	climate variables	reproduction number for COVID-19 cases	UV radiation explained a small proportion of global variation in reproduction number; no other significant associations with climatic variables were observed, except temperature within cities in China only
Miah M 2022	observational study using national surveillance data	Bangladesh	1 January 2022, to 31 March 2022	temperature, cloud cover, wind speed, relative humidity, air pressure	COVID-19 (omicron) case numbers	maximum temperature, sky clearness, wind speed, relative humidity, and air pressure were all significantly associated with COVID-19 omicron transmission
Mofijur M 2020	observational study using national surveillance data	Dhaka, Bangladesh	1 to 31 May 2020	humidity, air quality, minimum temperature, precipitation, maximum temperature, mean temperature, and wind speed	new COVID-19 cases	among the seven indicators, only two indicators: minimum temperature and average temperature, had a significant relationship with new COVID-19 cases; air quality index had a strong negative correlation with cumulative cases of COVID-19 in Dhaka city
Monamele 2017	retrospective observational study	Yaounde, Cameroon	January 2009 to November 2015	temperature, rainfall and humidity	confirmed influenza cases	no statistically significant association observed between influenza activity and weather variables
Mukherjee 2022	observational study using international surveillance data	26 countries	1 March to 20 Dec 2020	temperature and UV indices	incident COVID-19 cases	overall negative association between temperature, UV indices and COVID-19 cases
Mulder C 2021	observational study using national surveillance data	69 large cities and 13 large towns in Italy	January to June 2020	environmental, climatic, air pollutants	the diversified spread of the SARS-CoV-2 virus in the different urban domains	population density and average altitude were not correlated with COVID-19 case numbers; PM2.5 was positively correlated with case numbers
Murray 2011	observational study of human H5N1 cases (WHO case reports) and weather data from NOAA's National Climatic Data Center (Fourier time series analysis)	H5N1 human cases Indonesia (n = 135) and Egypt (n = 50),	1 January 2005 (Indonesia) or 2006 (Egypt) to 1 May 2008	season, temperature, precipitation, humidity	influenza A/H5N1	human H5N1 incidence in Egypt, but not in Indonesia, was strongly associated with meteorological variables, peaking in Egypt when precipitation was low, and temperature, absolute humidity and relative humidity were relatively moderate
Ngattia 2016	observational data using city surveillance data	Abidjan, Cote d'Ivoire	2007 to 2010.	weekly rainfall, humidity, and temperature	laboratory-confirmed influenza cases	the weekly number of influenza cases showed significant cross-correlation with certain prior weeks for both rainfall, and relative humidity
Nakada 2020	observational study using regional surveillance data; Spearman correlation test and sensitivity analysis performed.	São Paulo, Brazil	18 March to 6 July 2020	population density (also social distancing); UV radiation, temperature, wind speed, humidity, also population density and social distancing	Case rates of COVID-19	COVID-19 infection rate was found to be inversely correlated with both temperature and UV radiation. COVID-19 infection rate was positively correlated with population density (and negatively correlated with social isolation rate)
Nascimento 2006	ecological time-series study	São José dos Campos, Southeastern Brazil	2000 and 2001	air pollutants (SO ₂ , O ₃ , and PM ₁₀) and weather conditions (temperature and humidity)	pneumonia hospital admissions among children	air pollution was associated with hospital admissions for pneumonia among children: the 8-day cumulative effect estimate showed that an increase of 24.7mg/m ³ in PM ₁₀ concentration was associated by 9.8% higher increased pneumonia admission rate
Nascimento-Carvalho CM 2010	longitudinal study over 21 months using clinical samples: nasopharyngeal aspirate and blood analysed by time-resolved fluoroimmunoassay with monoclonal antibodies	184 children aged < 5years hospitalized for community-acquired pneumonia in Salvador, Brazil	September 2003 to May 2005	meteorological factors including relative humidity, rainfall; season	influenza A and B viruses, respiratory syncytial virus (RSV), parainfluenza virus types 1, 2, and 3, and adenovirus	parainfluenza and RSV presented marked seasonal patterns: overall viral infections correlated with relative humidity or precipitation; parainfluenza correlated with precipitation; respiratory syncytial virus correlated with air temperature or precipitation; adenovirus correlated with precipitation

Nenna R 2017	retrospective study using clinical samples: nasal washing samples	infants hospitalized for acute bronchiolitis	2004 to 2014	mean temperature, relative humidity and wind velocity; air pollutants: sulfur dioxide, nitrogen oxide, carbon monoxide, ozone, benzene and suspended particulate matter measuring less than 10 µm (PM10) and less than 2.5 µm (PM2.5)	respiratory syncytial virus (RSV), rhinovirus, human bocavirus, human metapneumovirus, other viruses	peak RSV activity correlated with cold temperatures and higher relative humidity; RSV-positive cases correlates positively with BZ, NOx, SO2, PM10 and PM2.5; the most predictive pollutant for RSV cases (at constant temperature and humidity) was benzene
Nichols GL 2021	long term retrospective study using national surveillance data	1989 to 2019	1989 to 2019	weather, season	respiratory infections including coronavirus; influenza A; respiratory syncytial virus; influenza B; human metapneumovirus; human bocavirus; adenovirus; rhinovirus	coronavirus infections had similar seasonal distribution to influenza A and bocavirus, with a winter peak between weeks 2 to 8. Most infections occurred at < 10 °C ambient; with daily average global radiation > 500 kJ/m ² /h; sunshine < 5 h per day; or where relative humidity >80%
Nittari 2021	observational study using national surveillance data	regions and cities in Italy	2020	UV index	incident cases of COVID-19	higher UV index associated with lower rates
Ogunjo S 2022	observational study using national surveillance data	seven locations in tropical Nigeria	15 December 2020 to 15 February 2021 (the harmattan period)	air pollution associated with the harmattan; temperature, humidity, UV	COVID-19 infection cases	particulate matter was significantly positively correlated with case numbers; temperature and humidity were negatively correlated in some regions
Olaka AS 2021	observational study using national surveillance data	Brazil	1 July to 31 October 2020	atmospheric pressure, temperature, relative humidity, wind speed, solar irradiation, sunlight, dew point temperature, and total precipitation	confirmed cases of COVID-19	there were significant correlations between COVID-19 cases and all meteorological parameters, except for total precipitation, with the strongest correlation with maximum wind speed in São Paulo; regression tree analysis demonstrated that the largest number of confirmed COVID-19 cases was associated with wind speed (between ≥0.3381 and <1.173 m/s), atmospheric pressure (<930.5mb), and solar radiation (<17.98e+3); lower case numbers were observed for wind speed <0.3381 m/s and temperature <23.86°C
Oliveira CR 2016	observational data using regional enhanced community surveillance data	Salvador state, Brazil	2009 and 2013	rainfall, temperature, relative humidity; also seasonality described	influenza-like illness (ILI)	influenza-like illness had a clear seasonal pattern with peaks between the 35-40th week of the year; no association was seen between influenza-like illness and precipitation, relative humidity or temperature
Orak NH 2022	observational data using national surveillance data	Turkey	8 February to 2 April 2021	meteorological variables, air pollution	new confirmed COVID-19 cases	there was a significant association between humidity and weekly confirmed COVID-19 cases; the cooler temperatures had a positive correlation with the occurrence of new confirmed cases; the low PM2.5 concentrations had a negative correlation with the number of new cases, while reducing SO2 concentrations may help decrease the number of new cases
Osman MA 2022	observational data using international surveillance data	South Africa, Morocco, Tunisia, and Ethiopia	29 Dec 2019 to 30 April 2021	meteorological variables	number of new cases COVID-19 per day	rising average temperature was associated with higher COVID-19 daily new cases in South Africa and Ethiopia but lower daily new cases in Morocco and Tunisia; in Tunisia, relative humidity and daily new cases of COVID-19 were positively correlated, while in the other three countries, they were negatively associated

Pagsuyoin SA 2022	observational study using national data	Maricopa in Arizona, Cook in Illinois, Los Angeles in California, Suffolk in Massachusetts, and New York County in New York, USA	15 February 2020 to 15 December 2020	meteorological variables and air quality	COVID-19 case numbers	during the first wave of the pandemic, cases were correlated with humidity in Maricopa, and temperature in Maricopa and Los Angeles; neither cases nor death counts were strongly correlated with air quality
Pahuja 2021	observational data using national surveillance data	New Delhi, India	14 March 2020 till 18 June 2020	temperature, humidity, wind speed,	COVID-19 cases, doubling time, reproduction number	case number doubling time had a strong positive correlation with temperature; case number reproduction number had strong negative correlation with temperature; there was no significant correlation with humidity or wind speed
Pan J 2021	ecological study	202 locations in 8 countries	up to June 2020	temperature, relative humidity, wind speed, and UV radiation	transmission capacity of COVID-19 as estimated by a reproduction number calculated from daily number of cases	no significant associations were observed
Pan M 2019	observational data using regional surveillance data	Panzhuhua city, China	2006-2015	weather variables, season	A/H3N2, seasonal A/H1N1, A/H1N1pdm09, Victoria and Yamagata influenza viruses	A/H3N2 showed an annual cycle with a peak in summer-autumn, while A/H1N1pdm09, Victoria and Yamagata exhibited an annual cycle with a peak in winter-spring; relative humidity was positively associated with A/H3N2 activity while negatively associated with Victoria activity; higher prevalence of A/H1N1pdm09 and Yamagata was associated with lower absolute humidity
Pani 2020	observational study using national data	Singapore	January 23 to May 31, 2020	meteorological variables	COVID-19 daily cases	temperature, dew point, relative humidity, absolute humidity, and water vapor showed positive significant correlation with COVID-19 cases
Pavel RS 2020	observational study using national data	Bangladesh	March to June 2020	temperature, relative humidity, rainfall, wind velocity	COVID-19 case numbers	a significant correlation was found between air quality indicators and COVID-19 case numbers; a strong linear relationship was found between temperature and relative humidity
Peci A 2019	observational study using environmental data obtained from four meteorological stations and patient data including clinical specimens	44,362 patient specimens were tested for influenza virus, Toronto, Canada	1 January 2010 to 31 December 2015	absolute humidity (AH), relative humidity (RH), temperature, and wind speed	influenza case numbers (influenza virus, influenza A virus, influenza A/H3N2 virus subtype, and influenza B)	our study found a negative association of both absolute humidity and temperature with influenza A and B virus infections; the association of relative humidity with influenza A and B viruses was unclear; temperature fluctuation was associated with increased numbers of influenza B virus infections
Peng 2009	retrospective observational study	12 million Medicare enrollees in 118 urban communities, USA	2000 to 2006	ambient levels of major PM2.5 chemical components [sulfate, nitrate, silicon, elemental carbon (EC), organic carbon matter (OCM), and sodium and ammonium ions], and weather	hospital admissions for respiratory disease (not specified as infections) as indicated from health insurance billing records	ambient levels of elemental carbon and organic carbon matter, pollutants which are generated primarily from vehicle emissions, diesel, and wood burning, were associated with the largest risks of emergency hospitalization across the major chemical constituents of PM2.5
Pineda Rojas 2021	case study of the first wave of COVID-19 pandemic in Buenos Aires, Argentina	Buenos Aires, Argentina	March to November 2020	relative humidity	incident COVID-19 cases	in winter months only, relative humidity strongly negatively associated with no. of cases
Pramanik 2022	observational study using national surveillance data	101 cities, Russia: 79 in humid continental and 22 in sub-arctic climate regions.	March 2020 to May 2021	climatic factors: air temperature, relative humidity, wind speed, sunshine, diurnal temperature change, temperature seasonality.	incident COVID-19 cases from WHO situation reports and Russian Ministry of Health	in humid continental regions, positive association between temperature seasonality or wind speed and increase in case rates; in subarctic regions, diurnal temperature range, humidity and temperature all positively associated with increased case rates

Prata D 2021	observational study using national surveillance data	27 state capitals, Brazil	26 February to 2 July 2020	climatic variables	COVID-19 cases	increased daily temperature mean was correlated with decreased and increased in incidence of COVID-19 in subtropical and tropical climates, respectively
Price 2019	retrospective observational study using samples collected in the course of healthcare	52,060 respiratory samples from patients in Edinburgh, Scotland. tested between 2009 and 2015	2009 to 2015	daily local meteorological data (temperature, relative humidity, "humidity range" and dew point	rhinovirus, adenovirus, influenza A & B viruses, human parainfluenza viruses 1–3 (HPIV), respiratory syncytial virus (RSV), human metapneumovirus (HMPV)	adenovirus, influenza viruses A, B, RSV and HMPV preferred low temperatures; RSV and influenza A virus preferred a narrow "humidity-range" and HPIV type 3 preferred the season with lower humidity
Qi H 2020	time series analysis using national surveillance data	30 Chinese provinces	20 January 2020 to 11 February 2020	daily average temperature (AT) and relative humidity (ARH)	daily counts of COVID-19 cases	in Hubei, ambient temperature and relative humidity showed significantly negative associations with COVID-19 with a significant interaction between them; these associations were not consistent throughout mainland China
Qiu J 2021	observational study using national surveillance data	China	10 Jan to 11 June 2020	air pollution, emperature, humidity (also looked at NPIs)	daily case incidence ratio, COVID-19	CO, O3, PM10 and PM2.5 were found positively linked with CIR, but the effect of NO2 was negative; the temperature had no significant association with case incidence ratio, and the daily minimum humidity was a significant negatively predictor
Rasul A 2022	observational study using international surveillance data	global	January 2020 to March 2021	wind speed, temperature, relative humidity, precipitation,	the case number reproduction number of COVID-19 cases	weak inverse relationship between the case number reproduction number of COVID-19 cases and wind speed, but a positive significant relationship with precipitation: lower COVID-19 cases were recorded with high wind speed and low precipitation; the case number reproduction number of COVID-19 infection assessed against air temperature, relative humidity, and precipitation was statistically significant; the association of climatic variables with COVID-19 infection varied geographically
Raza A 2020	observational study using national surveillance data	Pakistan	10 March 2020 to 25 August 2020	meteorological indicators (temperature, rainfall, and humidity)	total COVID-19 cases	COVID-19 cases and temperature showed a positive correlation; the correlation between rainfall and COVID-19 cases was negative; there was a negative correlation between humidity and the total COVID-19 cases
Rehman Y 2020	observational study using national surveillance data	Pakistan	10 March to 10 July 2020.	humidity, temperature, wind, and sun exposure	COVID-19 daily incidence rate, death rate	daily temperature, sun exposure, wind, and humidity were not significantly associated with daily incidence rate
Rouen 2020	observational study using international surveillance data: day-to-day micro-correlation analysis	9 outbreak locations: Lombardy, Italy; London, UK; Ile-de-France, France; Grand Est, France; Stockholm, Sweden; Tehran, Iran, New York City, USA; Seoul Capital region, South Korea; New South Wales state, Australia	1 January to 17 April 2020	atmospheric temperature (used as a proxy for seasonality)	COVID-19 case numbers	negative correlation between atmospheric temperature variations and daily new cases growth rates, in all nine outbreaks, with a median lag of 10 days
Roussel 2016	observational study using national surveillance data	11 regions in France	9 years:	15 climatic variables including temperature, humidity	influenza incidence as estimated by the sentinel network	at the epidemic scale, no impact of climatic factors was identified; at the intra-annual scale, six climatic variables had a significant impact: average temperature, absolute humidity, daily variation of absolute humidity, sunshine duration, relative humidity and daily variation of relative humidity

Rubin D 2020	observational study using national surveillance data	211 counties in the USA	25 February 2020 to 23 April 2020	temperature, population density and social distancing	COVID-19 cases generated by each incident case at a given time, estimated from daily case incidence data	higher temperate weather, as well as social distancing, lower population density, , were associated with a decreased estimated case number reproduction number for SARS-CoV-2 in counties across the United States
Rui 2021	observational study investigating state-level correlation between COVID-19 risk and weather/climate factors in the USA using a spatio-temporal multivariate time series model	States in the USA	15 March 2020 to 15 September 2020	weather/climate factors	daily confirmed cases of COVID-19	maximum temperature, minimum temperature, humidity, percentage of cloud coverage, and columnar density of total atmospheric ozone strongly associated with COVID-19 cases in many states
Runkle 2020	case-crossover design with a distributed lag nonlinear model: each COVID-19 case as its own control at before and after supposed transmission	selected US cities with relatively high COVID-19 caseloads	February to April 2020	meteorological parameters	COVID-19 case rates	short-term exposure to humidity was positively associated with COVID-19 case rates in four cities
Sabarathinam C 2022	observational study using global surveillance data	12 countries: South Korea, China, Malaysia, Singapore, India, Kuwait, Italy, Spain, France, Germany, UK, USA	15 February to 25 April 2020	temperature, relative humidity, wind speed, dew point, and precipitation	COVID-19 case rates to indicate transmission	transmission increased with an increase in temperature and a decrease in precipitation in all the countries; transmission was higher when temperature ranged from 45 to 55°F, humidity from 65 to 75%, and in low precipitation conditions
Saddik B 2022	cross-country comparison study	All 6 Gulf Cooperation Council countries: Bahrain, Kuwait, Oman, Qatar, Kingdom of Saudi Arabia, United Arab Emirates.	29 January 2020 to 30 March 2021	temperature, wind-speed and humidity	COVID-19 cases and deaths	all 6 Gulf Cooperation Council countries, except the UAE, reported a positive correlation between temperature and cases and deaths; wind speed was positively correlated with cases in Qatar, but negatively correlated with cases in United Arab Emirates and deaths in Saudi Arabia; humidity was positively correlated with cases and deaths in Oman, negatively correlated in Bahrain, Kuwait, Qatar and KSA but there was no correlation in United Arab Emirates.
Sahafizadeh 2021	observational study using national surveillance data	Bushehr province, Iran	April to June 2020	average maximum temperature, wet bulb temperature, hours of sunshine, dew,point	incidence of COVID-19	temperature and humidity were not related to COVID-19 incidence
Sajadi 2020	global ecological study	8 cities with substantial spread of COVID-19 (Wuhan, China; Tokyo, Japan; Daegu, South Korea; Qom, Iran; Milan, Italy; Paris, France; Seattle, US; and Madrid, Spain) and 42 cities without substantial community spread	1 Jan to 10 March 2020	temperature, humidity, and latitude	Community COVID-19 transmission, defined as at least 10 reported deaths in a country as of March 10, 2020	the distribution of substantial community outbreaks of COVID-19 along restricted latitude, temperature, and humidity measurements was consistent with the behavior of a seasonal respiratory virus
Samillan 2021	observational study using international surveillance data/ observational retrospective study. Multiple linear regression models.	1,287 districts in Peru	5 March 2020 to 27 June 2020	climate: temperature, precipitation, solar radiation, water vapour pressure, wind; and environmental factors: elevation, vegetation index, PM2.5, NO2; population density	cumulative cases and deaths from COVID-19, also case-fatality rate	geographical elevation, mean solar radiation, air quality, population density and green vegetation cover, as a socioeconomic proxy, associated with infection and mortality of SARS-CoV-2 in Peru; case-fatality rate was weakly associated with altitude
Sanchez-Lorenzo A 2021	observational study using international surveillance data	Europe	Dec 2019 to 28 March 2020	atmospheric circulation patterns	COVID-19 cases	anticyclonic conditions appeared to be associated with early spread of COVID-19 across Europe.; there were resemblances with spatial and atmospheric conditions during the 1918 Spanish flu

Sarmadi M 2021	observational study using national surveillance data	406 local authority areas, UK	29 Dec 2019 to 13 November 2020	temperature, dew point, wind speed, and humidity	COVID-19 cases and deaths	temperature, dew point, wind speed, and humidity were associated with case numbers and deaths from COVID-19; cases were negatively correlated with humidity in areas with high population density, but the inverse in low population density areas; wind speeds in low visibility (high pollution) areas were associated with increased transmission of cases disease; in high visibility areas high wind speeds were associated with decreased transmission; case numbers were higher in colder areas
Sarkodie SA 2020	observational study using international surveillance data	US, Spain, Italy, France, United Kingdom, Germany, Turkey, Russia, Iran, China, Brazil, Canada, Belgium, Netherlands, India, Switzerland, Peru, Portugal, Ecuador, and Saudi Arabia.	22 January to 27 April 2020	dew/frost point at 2m, maximum temperature at 2m, minimum temperature at 2m, wind speed at 2m, precipitation, relative humidity at 2m, surface pressure	confirmed cases and deaths, COVID-19	high temperature and high relative humidity associated with reduced COVID-19 cases & deaths; wind speed and surface pressure associated with higher confirmed cases of SARS-CoV-2; dew/frost point and precipitation associated with an increase in the incidence of COVID-19
Schlaudecker 2012	longitudinal clinic-based surveillance study over 16 months	children < 5 years of age presenting with respiratory symptoms of < 5 days duration, in a rural Honduran population	February 2010 - June 2011	seasonality, rainfall	parainfluenza, influenza, human metapneumovirus, respiratory syncytial virus.	rainfall correlated with parainfluenza, influenza, human metapneumovirus and respiratory syncytial virus
Schuck-Paim 2012	observational study using national surveillance data	Brazil	May 2009 (week 21) to May 2010 (week 21)	latitude	pneumonia, influenza, and pneumonia and influenza mortality	there was latitudinal gradient in laboratory confirmed mortality rates and in pneumonia & influenza mortality with pandemic impact gradually decreasing from South to North Brazil
Sehra 2020	observational study using national surveillance data, negative binomial regression modelling.	USA	22 Jan 2020 to 3 March 2020	temperature, precipitation and UV Index	Daily reported cases of SARS-CoV-2	transmission was lower with increasing temperature up until 11.1 degree Celsius; a 1-unit higher UV index was associated with a slightly lower rate at 5 days; precipitation was not associated
Selcuk M 2021	observational study using national surveillance data	81 provinces in Turkey	Dec 2019 to 1 April 2020	meteorological variables (and population density as a control variable)	Cases of SARS-CoV-2 infection	population density was positively correlated with COVID-19 cases; at lag day 3, all parameters except for sunshine duration were significantly negatively correlated with COVID-19 cases; only temperature, air pressure and dew point were significantly negatively correlated with COVID-19 cases lag days 0, 7 and 14; temperature, air pressure and dew point parameters were significantly negative correlated in all timeframes
Seposo X 2021	observational study using national surveillance data	Three cities in The Philippines	3 April 2020 to 2 September 2020	meteorological variables including daily average temperature, dew point, relative humidity, air pressure, windspeed and visibility	COVID-19 case reproduction number	same-day and the prior week's air pressure was positively associated with an increase in case reproduction rate
Sera 2021	cross-sectional analysis; case numbers from Multi-Country Multi-City Collaborative Research Network	409 cities across 26 countries	11 January to 28 April 2021	mean temperature, relative and absolute humidity, solar radiation, wind speed, precipitation	COVID-19 effective reproduction number	unadjusted analyses: no clear associations; adjusted for socioeconomic & demographic factors, a modest, non-monotonic association between mean temperature and the effective case reproduction number and between humidity and effective case reproduction number
Shahzad 2020	observational data using national surveillance data	four regions of Spain: Castilla y Leon, Castilla-La Mancha, Catalonia, Madrid	29 February to 17 July 2020.	daily average temperature, air quality	daily new cases of COVID-19	temperature not associated; rising temperature associated with lower case numbers; reduced air quality associated with higher case numbers

Shaman 2010	observational study using national surveillance data; correlations	continental USA	1972 to 2002	absolute humidity	influenza mortality	the onset of increased wintertime influenza-related mortality in the United States was associated with anomalously low absolute humidity levels during the prior weeks
Sharif 2021a	observational study using international surveillance data/ observational retrospective study	Japan	January 2020 to February 2021	meteorological factors, population density	incidence and fatalities from COVID-19	COVID-19 incidence was strongly correlated with average temperature, minimum temperature, UV index, sun hours, relative humidity, total population and population density. Relative humidity had the highest correlation with the case fatality rate
Sharif N 2021b	observational study using international surveillance data/ observational retrospective study	8 cities in Bangladesh	07 March 2020 to 14 August 2020	meteorological factors, population density	incidence and fatalities from COVID-19	among meteorological parameters, average temperature had the strongest correlation with the case numbers; population density, temperature, UV index and humidity were also correlated
Sharif N 2021c	observational study using international surveillance data	Cities and regions in Australia, Bangladesh, Brazil, India, Italy, South Africa, Spain, UK, USA	1 January 2020 to 30 June 2020	temperature, UV index, humidity, wind speed	COVID-19 case numbers	most of the COVID-19 cases and fatalities were detected from regions (New York, Madrid, Lombardy, London and Sao Paulo) with 7 °C to 25 °C mean temperature per day, 3 to 6 mean UV index per day and 14 km/h to 22 km/h mean wind velocity per day
Sharma GD 2021	observational study using international surveillance data	Brazil, Chile, India, Iran, Italy, Peru, Russia, Spain, the UK, and the USA	1 February 2020 through 30 June 2020	meteorological factors and air pollutants	COVID-19 confirmed cases	temperature and air pressure were significantly negatively associated with COVID-19 confirmed case numbers; PM2.5 was positively associated with COVID-19 confirmed case numbers; temperature was negatively associated with, and air pollutant PM2.5 was positively associated with, COVID-19 death numbers.
Shim SR 2022	observational study using national surveillance data	South Korea	20 January 2020 to 29 April 2020	air pollution, sunshine, temperature, wind, and air pollutants including sulphur dioxide, carbon monoxide, ozone, nitrogen dioxide, PM2.5, PM10	age-standardized incidence ratio of COVID-19	exposure to ambient air pollutants, especially sulphur dioxide and carbon monoxide were associated with SARS-CoV-2 infection
Shoji 2011	observational study using national surveillance data; multiple linear regression models	46 prefectures in Japan	1991 to 1995 and 1999 to 2009	absolute humidity	influenza cases (no further specification)	absolute humidity correlated strongly with influenza case numbers
Sil A 2020	observational study using international surveillance data	global	January 2020 to 15 March 2020	climate and meteorological variables including temperature	increase in case numbers of COVID-19	the growth rate of the global pandemic is related to the changes in temperature: a rise in temperature was associated with a slower growth rate in case numbers; the analysis suggested -6.28 °C and 14.51 °C, as the most the favorable temperature range for the growth of COVID-19
Singh O 2021	cross-sectional study using national surveillance data	Delhi region, India	14 March to 11 June 2020	climatic variables including maximum, minimum and mean temperature, relative humidity, bright sunshine hours, wind speed, evaporation, and rainfall	COVID-19 case numbers	among 8 climatic variables, maximum temperature, minimum temperature, mean temperature, relative humidity, evaporation, and wind speed were positively associated with coronavirus disease case numbers

Smith 2017	case-crossover analysis; associations between extreme precipitation and ER visits for influenza were estimated using conditional logistic regression	Massachusetts; each case was its own control at a time point before/ after the event of interest (i.e. self-matching)	2002–2008	extreme precipitation (\geq 99th percentile) events	risk of emergency room (ER) visit for influenza	extreme precipitation events were associated with increased emergency department visits for influenza at lag days 0 to 6; there was significant effect modification by race, with the strongest association observed among Blacks
Smith 2021	cross-sectional study using national surveillance data	states in the USA	NR, but publication was 2021	temperature, humidity, UV (also population density and policy measures)	SARS-CoV-2 transmission rates	temperature, humidity, and UV, which are themselves correlated, explain some of the variation in reproduction number across the country, the most important being cold temperatures. environmental associations were weaker than population density or policy interventions
Sobral MFF 2020	observational study using international surveillance data	global	1 December 2019 to 30 March 2020	meteorological variables including temperature, humidity, precipitation	COVID-19 infection numbers	negative association between country average temperature and COVID-19 infections; positive associations between country precipitation and COVID-19 infections; no association between deaths and country temperature or precipitation
Soebiyanto RP 2015	observational study using international surveillance data	9 sub-national areas with temperate and subtropical climates: Berlin (Germany), Ljubljana (Slovenia), Castile and León (Spain) and all 6 districts in Israel.	2000–2011 (Spain) and 2006–2011 (all others).	meteorological and season	weekly influenza-associated influenza-like-illness or acute respiratory infection incidence to represent influenza activity	influenza activity was inversely associated with specific humidity in all locations; minimum temperature was inversely associated with influenza in all 3 temperate locations, but not in all subtropical locations; inverse associations between influenza and solar radiation were found in most locations; associations with precipitation were location-dependent and inconclusive
Solanes 2021	observational study using national surveillance data	52 provinces, Spain	2 March to 19 April, 2020	meteorological factors: temperature, humidity, solar irradiation, pressure, wind, precipitation, cloud coverage	COVID-19 infection fatality rate (estimated as excess deaths)	the association between meteorological factors and adjusted COVID-19 infection fatality rate was unclear
Song P 2022	observational study using national surveillance data	China	10 January 2020 to 10 May 2021	altitude, air pollution, humidity	daily confirmed cases of COVID-19	preliminary linear regression analysis indicated a negative correlation between altitudes and COVID-19 infection; COVID-19 confirmed cases had a positive correlation with mobility, absolute humidity and altitude, whereas negatively correlated with SO ₂ , CO, and diurnal temperature range; subsequent mediating effect model with altitude-correlated factors, such as mobility, temperature, humidity, daily temperature range, and sulphur dioxide, largely explained differences in COVID-19 infection rate between low- and high-altitude regions
Spada A 2021	observational study using international surveillance data & structural equation modelling	209 countries	Dec 2019 to April 2020	climate variables, population density	COVID-19 case numbers	both climate and population density significantly associated with the spread of COVID-19; among the climatic factors, irradiation played the most relevant role, with a factor-loading of - 0.77, followed by temperature (- 0.56), humidity (0.52), precipitation (0.44), and pressure (0.073)
Storms 2013	observational study using international surveillance data	80 countries (47 temperate, 33 tropical–subtropical)	62 weeks from 11 June 2009 to 10 August 2010 (i.e. 2009 to 2010 pandemic period)	season, latitude	influenza, strain and rates globally	transmission of A(H1N1)pdm09 exhibited similarities with seasonal influenza transmission in that activity varied between temperate and tropical–subtropical countries and by time of year

Suman TY 2022	observational study using national surveillance data	Chennai, India	March 2020 to April 2021	season, temperature, wind speed, barometric pressure, air pollution	COVID-19 case numbers	there were seasonal variations in the number of COVID-19 cases; case increase was strongly associated with temperature, wind speed, nitric oxide and barometric pressure during summer seasons, whereas wind speed and barometric pressure were associated with case increase during rainy seasons; PM 2.5, NO and barometric pressure were associated with increased cases during winter seasons; these relationships fluctuated seasonally
Sun C 2022	observational study using international surveillance data	global	Dec 2019 to Sept 2021	air temperature, relative humidity, wind speed, and surface pressure,	COVID-19 case numbers	Air temperature was the most significant meteorological factor influencing the transmission of the COVID-19 epidemic. Except for a few areas, regional air temperature changes and the transmission of the epidemic showed a significant positive correlation. In different countries and regions studied, wind speed, relative humidity, and surface pressure show inconsistent correlation (and significance) with the number of diagnosed cases but show some regularity.
Sundell N 2016	retrospective study using clinical samples tested by PCR	20,062 clinical nasopharyngeal swab samples referred for detection of respiratory pathogens	October 2010 to July 2013	meteorological variables including temperature, humidity, vapour pressure	16 viral pathogens including RSV, metapneumovirus, influenza A, bocavirus, adenovirus	low temperature and vapour pressure were associated with weekly incidence of influenza A, respiratory syncytial virus, metapneumovirus, bocavirus and adenovirus but no association with relative humidity was found; the incidence of human rhinovirus and enterovirus was independent of temperature; during seasonal influenza A outbreaks, the weekly drop of average temperature (compared with the week before) was strongly associated with the influenza A incidence recorded the following week
Tamerius J 2015	observational study using national surveillance data	Mexico	May to December 2009	weather variables (also school terms)	influenza A/H1N1	very high levels of specific humidity, as present during summer in southeastern Mexico, were associated with greater influenza transmission
Tang JW 2009	observational study using regional hospital data and weather data and employing time-series analysis	public hospitals in Hong Kong's New Territory East Cluster, together with Hong Kong climate data	2000–2007	temperature, relative humidity, vapour pressure, other meteorological variables	daily virus incidence data	influenza A and RSV incidence increased with higher environmental relative humidity, whereas influenza B incidence decreased with higher environmental temperatures; other climate variables (including vapour pressure as a measure of absolute humidity) were not significantly related to the incidence of these respiratory viruses
Tang L 2021	observational study using national surveillance data	USA	17 April to 10 July 2020 for SARS-CoV-2. For CoVHKU1, CoVNL63, CoVOC43, and CoV229E: July 2018 to June 2020	monthly UV radiation dose	monthly average percent positive with SARS-CoV-2, CoVHKU1, CoVNL63, CoVOC43, and CoV229E	sunlight negatively correlated with CoVHKU1, CoVNL63, CoVOC43, and CoV229E; for SARS-CoV-2, there was mixed evidence of associations

Thai PQ 2015	observational study using national surveillance data	52 provinces in Vietnam	1993 to 2010	minimum, mean, maximum temperatures, absolute and relative humidities, rainfall and hours of sunshine, season	influenza-like-illness (ILI) incidence data	the intensity of ILI seasonality in Vietnam was best explained by the intensity of absolute humidity seasonality; ILI seasonality was weak in provinces experiencing weak seasonal fluctuations in absolute humidity, whereas ILI seasonality was strongest in provinces with pronounced absolute humidity seasonality
Thanapongtharm 2013	observational study using national surveillance data and geographical information system database	Thailand	1 October 2004 to 1 April 2005	proportion of land covered by flooding	case numbers of HPAI H5N1	in addition to other risk factors, the proportion of land covered by flooding along with expansion of rivers and streams, was a highly significant risk factor in the 2004 HPAI epidemic
Thangariyal S 2020	observational study using international surveillance data	138 countries globally	January 2020 to May 2020	duration of sunshine, average minimum temperature, and average maximum temperature	daily new cases and death due to COVID-19	Average maximum temperature and sunshine duration were significantly associated with COVID-19 confirmed cases, deceased, and recovered; average sunshine duration was inversely correlated with an increase in daily new cases and deaths
Tobias A 2021	observational study using regional surveillance data	Catalonia, Spaine	2 March and 30 June 2020	mean temperature, absolute humidity, solar radiation	cumulative incidence of COVID-19	the results showed a geographical association between meteorological factors and the cumulative incidence of COVID-19; warm and wet climates may reduce the incidence of COVID-19 in Catalonia
Toczylowski K 2021	observational study using regional surveillance data	Bialystok, Poland	2013 to 2019	meteorological variables and particulate matter concentration	incidence of influenza-like illness (ILI), as a proxy for the circulation of influenza viruses	results showed an exponential relationship between cumulative PM2.5 pollution and the incidence of ILI, which remained significant after adjusting for air temperatures and a long-term trend; pollution had the greatest effect during the same week, but the risk of ILI was increased for the four following weeks; risk of ILI was also increased by low air temperatures, low absolute humidity, and high wind speed
Tripathi V 2022	observational study using international surveillance data	global	March 2020 to February 2022	meteorological factors including sunlight, temperature, humidity, also season	case numbers of COVID-19	low temperatures and low sunlight might be additional risk factors for SARS-CoV-2 infectivity, mostly in northern hemisphere countries
Tuluri F 2022	observational study using state surveillance data	Mississippi, US	January 2020 to August 2021	temperature, humidity, dew point, wind speed, pressure, and precipitatio	daily increase in COVID-19 cases	negative correlations were found between temperature and COVID-19 incidence rate and between humidity and COVID-19 incidence rate
Tzampoglou 2020	observational study using international data	100 countries	March to May 2020	climatological and sociodemographic factors	COVID-19 case and death rates	statistically significant correlation between average atmospheric temperature and the COVID-19 case and death rates
Valero 2022	observational study using national surveillance data	52 provinces, Spain	March to May 2020	meteorological and geographical factors	cumulative incidence of COVID-19	COVID-19 total cumulative incidence, in all three waves, was lower in coastal than in inland provinces; it correlated negatively with mean air temperature and rainfall, and positively with altitude.
van Noort 2012	analysis of timeseries of influenza-like illness as monitored from by two independent symptomatic surveillance systems (Influenzanet and EISN)	The Netherlands, Belgium and Portugal	2003 to 2010	seasonality, absolute humidity and temperature	influenza-like illness	modest variation of ILI rates across seasons in temperate climates despite large variations in initial susceptibility of the population
Viboud C 2004	observational study using national surveillance data	France	1971 to 2002	El Niño Southern Oscillation (ENSO)	impact of influenza as assessed by influenza morbidity, excess mortality	the magnitude of El Niño Southern Oscillation was associated with the impact of influenza epidemic

Wan X 2022	time series study using global surveillance data	global (617 time series datasets)	Dec 2019 to April 2021	temperature, precipitation	COVID-19 transmission rates	average transmission rate was lower in warm climates over the world and in wet climates (with more precipitation) in Europe; the maximum transmission rate was lower in warm climates in the world, China and USA, and in wet climates in China
Wang B 2020b	observational study using national surveillance data.	63 cities of China	1 January to 2 March 2020	PM2.5, PM10, ambient temperature, absolute humidity (also population mobility)	daily confirmed cases of COVID-19	each 10 µg/m3 increase in the concentration of PM10 and PM2.5 was positively associated with confirmed cases of COVID-19
Wang Q 2021	observational study using national surveillance data	31 provincial-level regions (excluding Hong Kong, Macao, and Taiwan) and 337 prefecture-level cities, China	January to October 2020	air pollutants, meteorological data (also migration index data; government response strictness index data)	confirmed COVID-19 cases	among the meteorological variables, the daily average temperature, wind speed, precipitation, and new COVID-19 cases were negatively correlated; air pollution concentration and migration index were positively correlated with new confirmed cases
Wang Z-B 2020	longitudinal study over 10 years involving clinical specimens: nasopharyngeal swabs or aspirates were collected and tested	6,611 children with pneumonia admitted to 1 hospital in Chongqing, China	2009 to 2018	season; meteorological and air pollution indicators	influenza virus, respiratory syncytial virus (RSV), parainfluenza virus (PIV), human metapneumovirus (HMPV), human rhinovirus (HRV), and human coronavirus (HCoV, including OC43, 229E, NL63, and HKU-1	RSV and HRV predominantly circulated from October to February; PIV and HCoV peaked in May; influenza virus, HBoV, and HAdV had dual peaks in July to August and December to January; HMPV infection occurred throughout the whole year; weather and air pollution indicators evaluated 1 week before disease onset had the highest contributions of 62.53% to severity of pneumonia, (high SO2 concentration, lower surface temperature, wider temperature difference, high CO concentration, more precipitation, high PM2.5 concentration, higher wind speed, high NO2 concentration, and higher relative humidity)
Ward 2020	observational study using national surveillance data	New South Wales, Australia	Jan to 31 May 2020	climatic factors	COVID-19 cases	overall a decrease in relative humidity of was associated with an increase in cases; overall, there was no relationship with between cases and temperature, rainfall or wind speed
Wei J-T 2020	observational study using national surveillance data	China	29 Dec 2019 to 21 March 2020	(transport) and meteorological factors	COVID-19 cases	a higher attack rate of COVID-19 was significantly associated with lower average temperature, moderate cumulative precipitation and higher wind speed
Xiao S 2021	observational study using national surveillance data	China	1 December 2019 to 31 March 2020	meteorological factors including humidity, temperature	daily COVID-19 counts and effective reproduction number	for China overall, temperature and relative humidity were not associated with COVID-19 incidence; within central China there was a negative association between relative humidity and COVID-19 incidence; older population appeared to be more sensitive to meteorological conditions, but there was no obvious difference between sexes
Xie J 2020	observational study using national surveillance data	122 cities in China	23 January 2020, to 29 February 2020	meteorological factors	daily confirmed cases of COVID-19	the relationship between mean temperature and COVID-19 confirmed cases was approximately linear in the range of b3 °C and became flat above 3 °C

Xu B 2021	observational study using viral assessment of hospitalised cases of acute lower respiratory infection	81 sentinel hospitals in 22 provinces, mainland China; 28,369 hospitalised patients tested: 10,387 positive for at least one virus, including RSV (4,091 patients), influenza virus (2,665), human parainfluenza virus (2,185), adenovirus (1,478), human bocavirus (1,120), human coronavirus (637), human metapneumovirus (615)	1 Jan 2009 to 30 Sept 2013	temperature, atmospheric pressure, vapour pressure, and rainfall had most explanatory power on most respiratory viruses in each region.	respiratory syncytial virus (RSV), influenza virus, human parainfluenza virus, adenovirus, human metapneumovirus, human bocavirus, and human coronavirus	temperature, atmospheric pressure, vapour pressure, and rainfall had strong associations with acute lower respiratory tract infection hospital admissions in both northern and southern China; relative humidity had significant explanatory power for some viruses in the north but not in the south; hours of sunlight influenced circulation only for RSV and influenza viruses in the north, but for the majority of viruses in the south
Xu H 2020	observational study using national surveillance data	33 cities in China	29 January 2020 to 15 February 2020	air quality index (AQI), temperature, humidity	COVID-19-confirmed cases	air quality index with COVID-19-confirmed cases association was statistically significant in some cities; lag effect of AQI on confirmed cases was statistically significant on lag 1 to 3 days; AQI effect on the confirmed cases in temperature range of 10–20 °C may be stronger; impact of AQI on the spread of COVID-19 may be enhanced under low relative humidity
Xu 2021	observational global analysis	3,739 global locations	12 Dec 2019 to 22 April 2020	temperature, humidity, precipitation, snowfall, moon illumination, sunlight hours, ultraviolet index, cloud cover, wind speed and direction, and pressure data) and ambient air pollution (PM2.5, nitrogen dioxide, ozone, and sulphur dioxide)	effective reproduction number (RE) for transmission of SARS-CoV-2	moderate, negative relationship between the effective reproduction number and temperatures > 25°C; a U-shaped relationship with outdoor ultraviolet exposure, and weaker positive associations with air pressure, wind speed, precipitation, diurnal temperature, sulphur dioxide, and ozone; results were robust to multiple assumptions
Yang 2021	observational study using national surveillance data	Wuhan, Beijing, Urumqi and Dalian, China	8 Dec 2019 to 11 Nov 2020	daily maximum temperature, minimum temperature, average temperature, temperature range, relative humidity, average wind speed and total precipitation, season, geographical location	number of COVID-19 cases	in summer, in inland cities, increased relative humidity and decreased maximum temperature associated with higher COVID-19 cases; in coastal cities, decreased relative humidity associated with increased COVID-19 case numbers; in winter, in humid cities, lower relative humidity and the lower temperatures were associated with higher case numbers
Yang 2021	cross-sectional study using national surveillance data	provinces and 344 cities in China	25 January to 29 February 2020	climate (also socio-economic factors and spatial distance)	confirmed cases and deaths from COVID-19	relative humidity negatively correlated with case rates; temperature and solar radiation positively associated (other factors investigated had stronger relationships than these environmental factors)
Yao Y 2020	observational study using national surveillance data (letter)	China	29 Dec 2019 to 9 March 2020	meteorological data, including daily mean temperature and relative humidity, and UV radiation	confirmed COVID-19 cases	no association of temperature, relative humidity or UV radiation with COVID-19 cases
Yassin 2022	observational study using national surveillance data	State of Kuwait	24 Feb to 30 May 2020	atmospheric weather variables	daily COVID-19 cases from Ministry of Health	Infection rate was directly proportionate to air temperature, wind speed, visibility, and inversely related to humidity

Ye C 2019	observational study using local surveillance data; time-series seasonal decomposition analysis to investigate the seasonality of influenza	Pudong, Shanghai, China	2012 to 2018	seasons (and other epidemiological features)	Influenza-like illness (ILI)	semiannual epidemic peaks were identified in four of the 6 study years; one annual epidemic peak was found in the other two years; an epidemic peak occurred in each winter season, and a secondary peak also occasionally occurred in summer or spring; A/H3N2 predominated in both summer and winter, while A/H1N1, B/Yamagata, and B/Victoria circulated almost exclusively in winter or spring
Yin C 2022	observational study using national surveillance data (regression)	Brazil	25 February to 15 November 2020	daily average temperature, maximum temperature, minimum temperature, relative humidity, minimum relative humidity, wind speed, and precipitation	COVID-19 case numbers	cold, dry and windless conditions aggravated COVID-19 transmission; the daily average temperature, humidity, and wind speed negatively affected daily new cases; humidity and temperature played a dominant role in this process
Yuan J 2021b	observational study using international surveillance data; time-series analysis	188 countries	Dec 2019 to Dec 2020	daily mean temperature, daily maximum temperature, daily minimum temperature, dew point temperature, precipitation, and wind speed	daily new cases of COVID-19	mean temperature, wind speed and relative humidity were negatively correlated with daily new cases of COVID-19, and the diurnal temperature range was positively correlated with daily new cases of COVID-19; these relationships were more apparent when the temperature and relative humidity were lower than their average value
Yuan J 2021	observational study using international surveillance data	127 countries	Dec 2019 to 31 August 2020	meteorological factors including wind speed, relative humidity, temperature	COVID-19 cases	temperature, relative humidity, and wind speed were nonlinearly correlated with daily new cases
Yuan J 2006	observational study using national surveillance data (regression)	Beijing, China	3 April and 11 June 2003	temperature, relative humidity, and wind velocity	Severe acute respiratory syndrome (SARS)	the peak spread of SARS occurred at a mean temperature of 16.9 degrees Celsius, with a mean relative humidity of 52% and wind speed of 2.8 m/s
Zhang X 2022	observational study using national surveillance data	48 states, USA	23 March to 1 September 2020	temperature, specific humid, wind speed, shortwave radiation	daily new cases of COVID-19	weather variables were associated with case numbers; temperature and specific humidity were more critical than shortwave radiation, wind speed, and precipitation
Zhou D 2022	observational study using international surveillance data	China and Italy	20 January to 10 March 2020 and 21 May to 30 November 2021	latitude, temperature, wind speed, dew point temperature	daily confirmed new cases of COVID-19, by variant of concern (Alpha and Delta)	latitude was substantially connected with daily confirmed new instances of the Alpha variant of concern (VOC), while there was no such correlation with Delta VOC transmission; higher temperatures and increased wind speed were associated with reduced transmission of the Alpha and Delta VOCs
Zhang Y 2020	observational study using city disease registration data (generalized linear models, distributed lag non-linear models and regression tree models applied)	Shanghai, China	June 2012 to December 2018	mean temperature, diurnal temperature range, relative humidity and wind velocity	influenza A and B	diurnal temperature range of 12 degrees C and mean temperature <22 degrees C were the key drivers for Flu-A and Flu-B, respectively; the study found complex non-linear relationships between climate variability and different influenza types in Shanghai
Zhang Z 2020	observational study using national surveillance data	219 prefecture cities, China	24 January to 29 February 2020	meteorological conditions and air pollution	new confirmed cases of COVID-19	results revealed a nonlinear dose-response relationship between temperature and coronavirus transmission; the study also found that air pollution indicators were positively correlated with new confirmed cases, and the coronavirus further spreads by 5-7% as the air quality index increased by 10 units

Zhou J 2021	observational study using national surveillance data	120 cities, Chinese	15 Jan to 18 Mar 2020	PM2.5, NO2, SO2, CO, and O3, average temperature, diurnal temperature range, relative humidity, wind velocity, air pressure, precipitation, and hours of sunshine	total confirmed cases of COVID-19	positive associations found between the number of confirmed cases of COVID-19 and CO, PM2.5, relative humidity, and O3, with and without population movement adjustment; negative associations were found for SO2 and wind velocity both with and without controlling for population migration; air pollutants and meteorological factors had interactive effects on COVID-19 after controlling for population movement
Zhou 2022	ecological study	four US states with the highest COVID-19 rates at the time: California, Florida, New York, Texas.	12 April 2020 to 13 October 2020	meteorological factors including wind speed, precipitation, temperature; and air pollution PM2.5 and AQI	confirmed COVID-19 cases data from Johns Hopkins Coronavirus Resource Center	temperature, wind speed, PM2.5 and AQI all showed a significant correlation with the number of COVID-19 cases; relationship of temperature and PM2.5 with COVID-19 cases unclear
Zhu L 2020	observational study using international surveillance data	8 regions across Peru, Ecuador, Brazil and Chile	Dec 2019 to 12 May 2020	meteorological factors including average temperature, maximum temperature, minimum temperature, average wind speed, visibility, absolute humidity	COVID-19 transmission estimated from confirmed case numbers	absolute humidity was negatively correlated to the spread of COVID-19 in the selected regions
Zoran MA 2022	observational study using regional surveillance data	Madrid, Spain	1 January 2020 to 1 July 2021	temperature, surface solar irradiation, air pollution PM2.5, PM10, O3 and NO2	daily new COVID-19 incidence and deaths	there was a significant negative correlation of air temperature and surface solar irradiance with daily new COVID-19 incidence and deaths; daily average ground levels ozone concentrations were significant negative correlated with daily new deaths, and daily average ground levels of nitrogen dioxide were positive correlated with daily new deaths
Zoran MA 2022b	observational study using national surveillance data	Bucharest, Romania	1 January 2020 to 21 December 2021	radon levels, air pollution, air circulation patterns	COVID-19 incidence and deaths	daily outdoor exposures to air pollutants (particulate matter PM2.5 and PM10, nitrogen dioxide-NO2, sulfur dioxide-SO2, carbon monoxide-CO) and radon - 222Rn, were directly correlated with daily COVID-19 incidence and mortality; daily ground ozone-O3 levels, air temperature, Planetary Boundary Layer height, and surface solar irradiance were negatively correlated with daily new COVID-19 incidence and deaths.