

Rapid evidence checks are based on a simplified review method and may not be entirely exhaustive, but aim to provide a balanced assessment of what is already known about a specific problem or issue. This brief has not been peer-reviewed and should not be a substitute for individual clinical judgement, nor is it an endorsed position of NSW Health.

Winter and COVID-19 transmission

Rapid review question

How will seasonal changes impact the COVID-19 pandemic?

In brief

- A number of models explore the association between seasonal changes and COVID-19 transmission:
 - Some models show the distribution of outbreaks occur along a restricted latitude, or in countries with high humidity and low temperatures, or dry and cold temperatures, which is consistent with the behaviour of a seasonal respiratory virus
 - So early in the pandemic, correlations are weak and there is insufficient evidence to determine whether COVID-19 will behave seasonally like influenza; or will spread in all seasons like MERS
- There is consistent advice about the need to replicate analyses and models incorporating new data as the pandemic progresses
- The Centre for Evidence-Based Medicine published a review on weather conditions and transmissions, concluding emerging evidence appears to suggest weather conditions may influence transmission, however all estimates are subject to significant biases.

Methods (Appendix 1)

PubMed and Google were searched on 1 April 2020. Studies were included if they referred to seasonal changes and coronaviruses and influenza together, or if they referred to seasonal changes and COVID-19. Exclusion criteria were no abstract was available, a focus on influenza without consideration of coronaviruses.

Results (Tables 1 and 2)

Preliminary models show some correlation between seasonal changes and cases of COVID-19 (1-5) and there are calls for further studies to determine high risk areas of transmission during seasonal change for healthcare planning purposes (6,7). Some studies note the transmission of Middle Eastern Respiratory Syndrome (MERS) did not respond to seasonal changes and that there could be other variables involved in slowing transmissions of the virus in coming months (6-8).

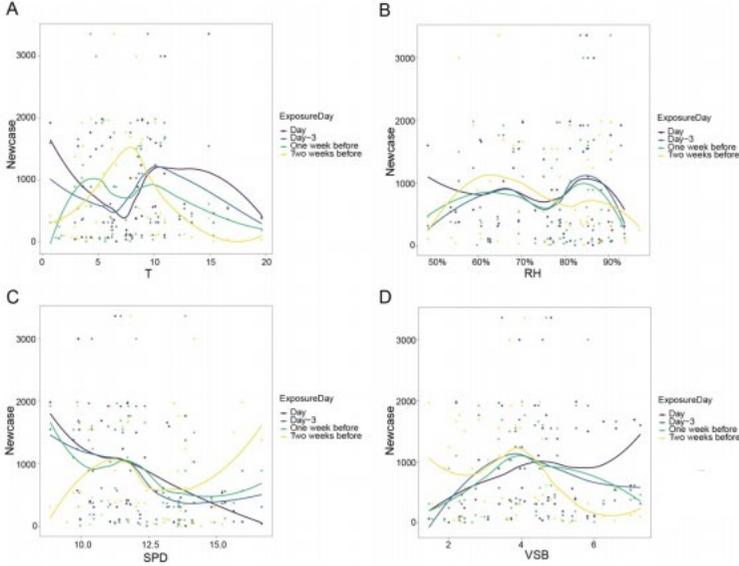
Data in the below tables may be skewed as models may not have taken into account other variables that affect COVID-19 transmission, for example; minimal testing per city per country, population density, community structures, social dynamics, government policies and global connectivity. Table One gives insight into modelling used to assess the impact of seasonal changes on COVID-19 transmission. Opinion pieces on the effects of winter on the transmission of COVID-19 are included in Table Two.

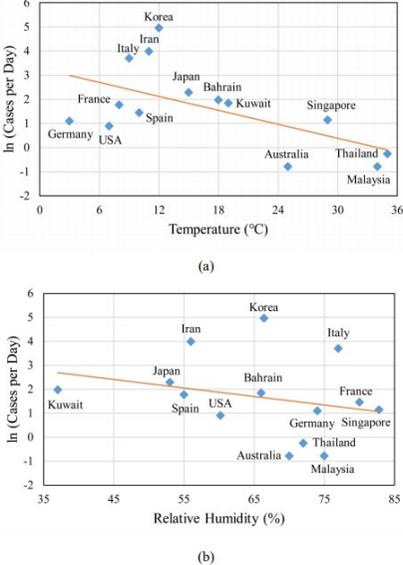
Table 1: Mathematical Models – The effect of seasonal changes on COVID-19 transmission

Study	Country	Study type	Results
Brassey et al. 2020	UK	Evidence review	Although much of the data has not been peer-reviewed yet, emerging evidence appears to suggest that weather conditions may influence the transmission of the novel coronavirus (SARS-CoV-2), with cold and dry conditions appearing to boost the spread. This phenomenon may manifest itself through two mechanisms: the stability of the virus and the effect of the weather on the host. The weather effect is minimal, and all estimates are subject to significant biases reinforcing the need for robust public health measures.
Neher, 2020	Switzerland	Modelling	<p>Explores how seasonal variation in transmissibility could modulate a COVID-19 pandemic</p> <p>Uses data from routine diagnostics that show a strong and seasonal variation of four endemic coronaviruses (229E, HKU1, NL63, OC43) and parameterises a model for COVID-19 using these data.</p> <p>Simulations of different scenarios show that plausible parameters result in a small peak in early 2020 in temperate regions of the Northern Hemisphere and a larger peak in winter 2020/2021 in the Northern Hemisphere.</p> <p>Study notes uncertainty of parameters is large, the scenarios explored in the models show that a reduction in the incidence rate of the virus could be due to a combination of seasonal variation and infection control efforts.</p>
Sajadi, 2020	US	Observational Modelling	<p>Study findings suggest that the distribution of community outbreaks along a restricted latitude, temperature and humidity are consistent with the behaviour of a seasonal respiratory virus.</p> <p>Study used ERA-5 reanalysis to examine climate data from cities with significant COVID-19 transmission and compared data to areas that are not affected or do not have community spread.</p> <p>It was found that while there is an association between average temperature, humidity (average temperature (5-11C) and RH (44-84%)), and the number of COVID-19 transmissions, there is not enough correlation to suggest that COVID-19 will behave seasonally like the flu or like MERS (with an ability to spread in all seasons).</p> <p>Study advises using weather modelling could predict regions with a higher risk of COVID-19 community transmission.</p>
Araujo, 2020	Spain	Observational modelling	<p>Existing data was used to develop a large ensemble of ecological models that project monthly variation in climate suitability of SARS-CoV-2 throughout a typical climatological year.</p> <p>Analysis of all positive cases of SARS-CoV-2 Coronavirus plotted against monthly temperature and precipitation values reveal that the interquartile range of average environmental temperatures associated with positive cases so far is between -4.01°C to 15.58°C (99% range) and -2.04°C to 9.49°C (95% range). For precipitation, the interquartile range ranges from 4.68 mm to 116.06 mm (99% range) and 19,75 mm to 94,43 mm (95% range). Analysis reveals that SARS-CoV-2 thrives in warm temperate climates between October to</p>

Study	Country	Study type	Results
			<p>May and cold temperate climates between April and September. Arid environments follow the temperate warm trend of seasonal probability of contracting the SARS-CoV-2 Coronavirus but with generally more moderate levels. The tropics have low levels of climate suitability for spread of SARS-CoV-2 Coronavirus owing to their high temperatures and precipitation (used here as a surrogate for humidity), followed by polar climates, where conditions of extreme cold temperatures seem to be beyond the virus critical minimum tolerance values</p> <p>Author explains from June to September, much of higher latitude regions of the southern hemisphere, like Argentina, Australia, Brazil, Chile, New Zealand, and Southern Africa will likely be become exposed to new outbreaks of SARS-CoV-2. The model also projects highest latitude regions of the northern hemisphere to be badly hit by the Coronavirus during this period, including Canada and Russia, but also the Scandinavian countries. High elevation areas in the Andes and the Himalayas share the same prospects. Concurrently the northern hemisphere (Italy, Spain, France, Germany, UK, and USA) should witness a reduction in the incidence of new positive cases SARS-CoV-2 Coronavirus.</p>
Bannister-Tyrrell, 2020	Australia		<p>Study used global line-list data on COVID-19 cases up to the 29 February 2020 and global gridded temperature data. After adjusting for surveillance capacity and time since first recorded case, higher average temperature was strongly associated with lower COVID-19 incidence for temperature of 1 degree Celsius and higher.</p> <div data-bbox="712 715 1413 1102" data-label="Figure"> </div> <p><i>Figure 2: Predicted number of local cases of COVID-19 by 1st-level administrative unit as a function of the average temperature during the period from the first reported case until 29th February 2020. The grey area represents the 95% confidence interval of the predicted values.</i></p> <p>Study advised the evidence is preliminary and that cases included ranged from the first reported case in China to the 29 February, providing limited data. It was noted that countries need to replicate analysis as the pandemic progresses, as the study finding suggest that there may be seasonal variability in transmission of COVID-19.</p>
Chen,			Study used modelling to examine the relationship of meteorological variables with the severity of the outbreak



Study	Country	Study type	Results
2020			<p>on a worldwide scale. Study used confirmed case counts, to indicate the severity of COVID-19 spread, and four meteorological variables: Air temperature, humidity, wind speed and visibility. These variables were collected daily between January 20 and March 11 (52 days) for 430 cities and districts in China, 21 provinces in Italy, 21 provinces in Japan, and 51 other countries around the world.</p>  <p>Figure 1. Loess regression interpolation of confirmed new case counts to the four meteorological variables, (A) average temperature (T) in °C, (B) relative humidity (RH) in %, (C) wind speed (SPD) in miles per hour, (D) visibility (VSB) in statute miles to nearest tenth, for Wuhan city. Four time delay of the confirmation day (when epidemiological data were correlated) from the exposure day (when weather data was correlated) are displayed together in one figure, namely, exposure on the day, three days before, one week before, two weeks before.</p> <p>The regression showed that there is a relationship between weather and COVID-19. Another model used Wuhan data for single factor modelling to produce better model fitness. According to the equation, COVID-19 transmission reaches a peak when the air temperature is 8.07 °C, or when the wind speed is 16.1 mile/hr, or when the visibility is 2.99 statute miles to nearest tenth, or when the relative humidity is 64.6%.</p>
Wang, 2020	China	Observational	<p>Investigates how air temperature and humidity influence the transmission of COVID-19. Study references that the transmission of viruses can be affected by a number of factors including climate conditions such as temperature and humidity. The study also quoted Michael Ryan, executive director of the WHO Health Emergencies Program who stated that people still do not know the activity and behaviour of the COVID-19 virus in different climate conditions (March 06 2020).</p>

Study	Country	Study type	Results
			<p>The study used a linear regression framework for 11 Chinese provinces and 4,711 cases from survey data from the Centre for Disease Control and Prevention. It was concluded that high temperature and relative humidity reduce the transmission of COVID-19.</p> <p>The Figure 1 below shows the natural log of the average number of cases per day from 08 to 20 February 2020 to map the severity of COVID-19 outbreak for certain countries.</p>  <p>Figure 1: Severity of COVID-19 outbreaks v.s. temperature and relative humidity for countries outside China.</p> <p>The mathematical equation in this study shows that normal summer temperatures of around 28 degrees Celsius and humidity of 85% show that the transmission of COVID-19 will reduce. Risk remains in the southern hemisphere, especially with the increase of influenza in the winter.</p>
Wang Mao, 2020	China		<p>Study population collected were from daily confirmed new cases of COVID-19 officially reported in China and overseas, and the number of cumulative total confirmed cases in all cities and regions from January 20 to February 4 2020.</p> <p>There were in total 24,139 confirmed cases in 34 provinces (including municipalities, autonomous regions and special administrative regions) in China and 26 overseas countries.</p>

Study	Country	Study type	Results																														
			Results showed a significant impact of different temperature exposure on the human-to-human transmission of COVID-19. It was also found that there exists a nonlinear dose-response relationship, which means that a best temperature might exist for the transmission and that lower temperatures can contribute to the growth and transmission of the virus. The fact that the outbreak emerged in Wuhan and its neighbouring areas could be closely related to the temperature of the local region.																														
Luo, 2020			<p>Study examines province-level variability of COVID-19 infections across China. Study advises that weather alone will not necessarily lead to decline in COVID-19 case counts without implementation of public health interventions and advises further studies on the effects of absolute humidity and temperature on COVID-19 transmissions are needed.</p> <p>Regression model results demonstrate both absolute humidity and temperature are associated with local exponential growth of COVID-19 across provinces in China and other affected countries (Table 1). Absolute humidity and temperature yielded a positive relationship and a slight negative relationship respectively.</p> <table border="1"> <tr> <td>Number of observations</td> <td>37</td> </tr> <tr> <td>F-statistic</td> <td>4.878</td> </tr> <tr> <td>P-value (F-statistic)</td> <td>0.01372</td> </tr> <tr> <td>R-squared</td> <td>0.223</td> </tr> <tr> <td>Adjusted R-squared</td> <td>0.1773</td> </tr> </table> <table border="1"> <thead> <tr> <th>Variable</th> <th>Coefficient</th> <th>Std Error</th> <th>T-Statistic</th> <th>P-value</th> </tr> </thead> <tbody> <tr> <td>Intercept</td> <td>5.36×10^{-17}</td> <td>0.149</td> <td>0.00</td> <td>1.00</td> </tr> <tr> <td>Absolute Humidity</td> <td>0.761</td> <td>0.370</td> <td>2.054</td> <td>0.048</td> </tr> <tr> <td>Temperature Mean</td> <td>-1.050</td> <td>0.370</td> <td>-2.836</td> <td>0.008</td> </tr> </tbody> </table> <p>Table 1: Relationship between local exponential growth, $\log(R_{proxy})$, and environmental factors (i.e., absolute humidity and temperature).</p>	Number of observations	37	F-statistic	4.878	P-value (F-statistic)	0.01372	R-squared	0.223	Adjusted R-squared	0.1773	Variable	Coefficient	Std Error	T-Statistic	P-value	Intercept	5.36×10^{-17}	0.149	0.00	1.00	Absolute Humidity	0.761	0.370	2.054	0.048	Temperature Mean	-1.050	0.370	-2.836	0.008
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Bukhari, 2020	US		<p>Researchers analyse patterns in local weather of regions effected by COVID-19, until March 22 2020. They found for each 10 day period between January 22 to March 21 2020, the maximum number of new cases developed in regions had a mean temperature between 4 to 17C and an absolute humidity between 3 and 9 g/m³.</p> <p>Results show that the number of cases for temperature > 17C and absolute humidity > 9 g/m³ are low. Except for new cases between March 11 to March 21, 2020 (figure 4), the number of cases above 11C and below 0C was less than 5% and the total number of cases in regions with absolute humidity > 9 g/m³ was less than 10% (figure 4). Between March 11 and 19 2020 there was a surge in the number of cases in regions with temperature >18C, however it was lower than the surge in cases between 8 and 12C (figure 4).</p>																														

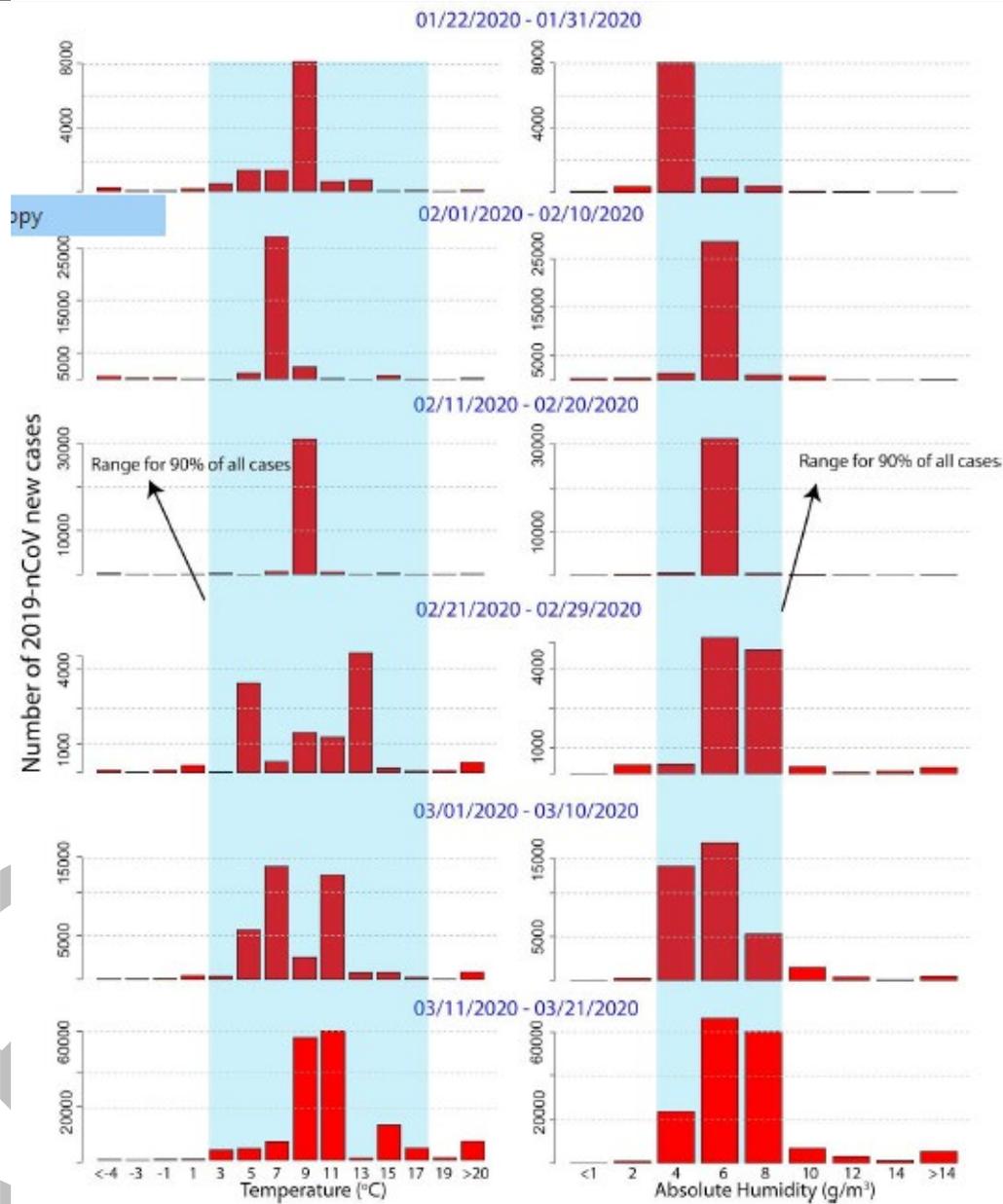


Figure 4: Number of 2019-nCoV cases across the world as a function of temperature and absolute-humidity. The figure shows the number of cases reported 2019-nCoV cases per 10 day period for different temperature and absolute humidity values. Temperature and absolute humidity range with the majority of 2019-nCoV cases (>90%) is highlighted with light blue color, and is consistently between 3 and 17 degree C for temperature and between 4 and 8 g/m³ for absolute humidity every week.

Study	Country	Study type	Results

Table 2: Opinion pieces – The effect of seasonal changes on COVID-19 transmission

Source Title	Advice	Source Link
Updated COVID-19 statistics and analysis	<ul style="list-style-type: none"> Article split cases into: <ul style="list-style-type: none"> Winter countries (Northern Hemisphere) Summer/Equatorial countries COVID-19 statistics are based on where the case was caught rather than diagnoses <p>Total Cases Caught Ex-China - by season where caught</p> <p>Total Cases Caught Ex-China - by season where caught</p>	https://nucleuswealth.com/articles/updated-coronavirus-statistics-cases-deaths-mortality-rate/#is-winter-an-issue
What effect will winter have on coronavirus in	<ul style="list-style-type: none"> Advice from Professor Tom Kotsimbos of Monash University suggests that the new virus may not be dependent on temperature or that the dependence on temperature is not as 	https://www.theguardian.com/world/2020/mar/17/what-



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Australia?	<p>important as the lack of immunity in the population, as the virus has spread quickly over the northern and southern hemispheres.</p> <ul style="list-style-type: none"> • Dr Meru Sheel of the National Centre for Epidemiology and Population Health at Australian National University advises that there is no clear evidence to suggest a relationship between outdoor temperatures and the spread of coronavirus. • Dr Chris Burrell emeritus professor of virology at the University of Adelaide advised that transmission of the virus may change in seasonally due to the way people behave, more people congregate inside during the winter. • Dr Kirsty Short, a virologist at the University of Queensland advised that combining a moderate flu season with moderate coronavirus could be problematic for the healthcare system 	effect-will-winter-have-on-coronavirus-in-australia
Will Warmer Weather Stop the Spread of the Coronavirus? Don't Count on It, Say Experts	<ul style="list-style-type: none"> • Article cites a study at the Massachusetts Institute of Technology found that the transmission of coronavirus had occurred most frequently in regions with colder annual average temperatures • A Chinese study found that cities that were warmer and were more humid had a slower rate of infection • Researchers in Spain and Finland found that 95% of infections globally have occurred at temperatures between -2 to 10 degrees Celsius and in dry climates • News article noted that infections have still spread in hot and humid weather, for example Malaysia. • Dr Nancy Messonnier of the Centers for Disease Control and Prevention warned against assuming cases will slow as the weather warms, she advised at least a year would be needed to further understand the pathogens transmission 	https://time.com/5790880/coronavirus-warm-weather-summer/
Warmer weather could slow the spread of coronavirus—but not by much	<ul style="list-style-type: none"> • Article cites a study which uses data compiled by Johns Hopkins University. Study found that the maximum number of coronavirus transmissions have occurred in regions that had temperatures between 3 and 13 degrees Celsius during the outbreak. • Countries with temperatures above 18 degrees Celsius have seen fewer than 5% of total cases. 	https://www.technologyreview.com/s/615381/coronavirus-spread-could-slow-with-warmer-weather/



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	 <p>Chart: MIT Technology Review · Source: Johns Hopkins CSSE · Get the data · Created with Datawrapper</p>	
<p>Seasonality of SARS-CoV-2: Will COVID-19 go away on its own in warmer weather?</p>	<p>Article lists factors which effect the transmission of respiratory viruses, including seasonal coronaviruses, as reasons for suspecting that COVID-19 will behave the same way:</p> <ul style="list-style-type: none"> • The environment: Humidity strongly affects flu transmission • Human behaviour: People spend more time indoors with less ventilation and personal space than outdoors in the summer. • Host immunity: Possible that an average person’s immune system is systematically worse in winter than summer • Depletion of susceptible hosts: Portion of susceptible contacts decline throughout infection disease epidemic 	<p>https://ccdd.hsph.harvard.edu/will-covid-19-go-away-on-its-own-in-warmer-weather/</p>
<p>Will warm weather really kill off Covid-19?</p>	<ul style="list-style-type: none"> • Article noted a study conducted 10 years ago by Kate Templeton, from the Centre for Infectious Diseases at the University of Edinburgh, UK, which found that three coronaviruses – all obtained from patients with respiratory tract infections at hospitals and GP surgeries in Edinburgh – showed “marked winter seasonality”. • An unpublished analysis comparing the weather in 500 locations around the world where there have been Covid-19 cases seems to suggest a link between the spread of the virus and temperature, wind speed and relative humidity. • Another unpublished study cited in the article has also shown higher temperatures are linked to lower incidence of Covid-19, but notes that temperature alone cannot account for the global variation in incidence. • The article also cited published research which predicts that temperate warm and cold climates are the most vulnerable to the current Covid-19 outbreak, followed by arid regions. Tropical parts of the world are likely to be least affected. 	<p>https://www.bbc.com/future/article/20200323-coronavirus-will-hot-weather-kill-covid-19</p>



Appendix one

PubMed Search string: ((((((covid-19[title/abstract] or covid19[title/abstract or SARS-COV-2 [title/abstract]])))))) AND (“winter”[title/abstract]))

PubMed Search string: ((((((covid-19[title/abstract]])))))) AND (“climate”[title/abstract]))

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