Influence of weather on Corona-Virus infections

An analysis of infections in 21 countries as a function of weather from 01. January to 18.March 2020

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0 Introduction

0.1 Company

meteoblue AG (thereafter named “meteoblue”) is a Swiss specialist company producing, managing and supplying high precision weather and environmental data for the entire world, using observation data, high-resolution Numerical Weather Predictions (NWP) and specialised data output methods adapted to the needs of different user groups. Available weather data archives cover 10 years in maximum precision and reach back until 1984 in hourly steps.

The data are calibrated globally and regularly verified in both live operation and historic reviews. Quality verification results are shown on https://content.meteoblue.com/en/verified-quality/verification.

0.2 Objective

With this document, we contribute to the knowledge of and defence against the new Corona-Virus (SARS-CoV-2) and the resulting disease infections (COVID-19), by providing a first analysis of the relationship between the infection spread and weather variables (parameters).

This knowledge is aimed at contributing to the estimate of further risk during the summer season in the Northern Hemisphere.

0.3 Methods

The results of this document have been obtained using publicly available data on Corona-Virus disease infections (COVID-19) from reputable sources and validated weather data from the meteoblue archives, using scientific and documented methods. The results are made available immediately, given the level of public interest and necessity. They have not been peer reviewed, and will be submitted to proper review in due course. Any feedback aimed at improving the methods and results are appreciated.

0.4 Distribution

This document is public and meant to be distributed any person interested in this project. If content is cited, please refer to the source and make sure it is properly explained in context.

1 Objectives

The objectives of this study are to

1. determine possible correlations between the new Corona-Virus (SARS-CoV-2) disease infections (COVID-19) in relation to weather variables (parameters).
2. contribute to the estimate of further risk of COVID-19 infections during the upcoming summer season in the Northern Hemisphere.
3. test the methodology of combining public data on COVID-19 infections with historical weather simulations data.
4. contribute to the further knowledge of COVID-19 infections in a rapid way.

Suggestions for further work and collaboration are very welcome (direct to info@meteoblue.com).

2 Materials and Methods

2.1 COVID-19 infection Data sources

COVID-19 infection data was obtained from the European Centre for Diseases Prevention and Control (https://www.ecdc.europa.eu/en/publications-data/download-todays-data-geographic-distribution-covid-19-cases-worldwide), for the period of 31.12.2019 until 18.03.2020. The data report the number of new documented cases and deaths per country and day.

To allow for a representative analysis, we selected countries with a minimum number of 250 infections in March 2020, with a minimum of 50 new cases in the period of 01.03.2020-10.03.2020, resulting in 21 countries from 5 continents and all global climate zones (see Table 2.1), with a total of 103'814 cases over a period of 80 days.

For weather data retrieval, one representative city was selected for each country based on the major reported first outbreak centre (source: en.wikipedia.org/wiki/2019–20_coronavirus_pandemic). It is known that outbreaks happened in several places, yet for a first analysis, these data are not available in sufficient detail for most countries. From a meteorological aspect, an approximation by one city is sufficient, since weather variables are expected to vary much less within most of the countries considered than between them.

For a more detailed (Second) analysis, eleven countries were selected, according to the largest number of new cases and the coverage of different climate (temperature) zones.

Table 2.1: Selection of countries, with number of daily new infections (Detection) in March 2020 (Source: European Centre for Diseases Prevention and Control) and cities selected for first and second analysis.

Continent	ID	Countries and territories	Detections	Capital	City used	2nd
EU	IT	Italy	30'618	Rome	Milano	1
AS	IR	Iran	15'781	Teheran	Teheran	1
EU	ES	Spain	11'144	Madrid	Madrid	1
EU	FR	France	7'673	Paris	Paris	1
EU	DE	Germany	7'099	Berlin	Heinsberg	1
NA	US	United States of America	6'361	Washington	San Francisco	1
AS	KR	South_Korea	5'482	Seoul	Seoul	
EU	CH	Switzerland	2'638	Bern	Bern	
EU	UK	United_Kingdom	1'932	London	London	
AS	CN	China	1'808	Beijing	Wuhan	1
EU	NL	Netherlands	1'703	The Hague	The Hague	
EU	AT	Austria	1'325	Wien	Wien	
EU	NO	Norway	1'302	Oslo	Oslo	
EU	BE	Belgium	1'242	Brussels	Brussels	
EU	SE	Sweden	1'155	Stockholm	Stockholm	
EU	DK	Denmark	1'022	Copenhagen	Copenhagen	
AS	MY	Malaysia	648	Kuala Lumpur	Kuala Lumpur	1
AS	JP	Japan	599	Tokyo	Tokyo	
NA	CA	Canada	553	Ottawa	Vancouver	
EU	PT	Portugal	448	Lisbon	Lisbon	
AS	QA	Qatar	442	Doha	Doha	1
EU	CZ	Czech Republic	434	Prague	Prague	
OC	AU	Australia	429	Canberra	Sydney	1
AS	IL	Israel	420	TelAviv	TelAviv	
EU	EL	Greece	383	Athens	Athens	
EU	FI	Finland	316	Helsinki	Helsinki	
EU	IE	Ireland	292	Dublin	Dublin	
LA	BR	Brazil	290	Brasilia	São Paulo	1
EU	SI	Slovenia	275	Ljubljana	Ljubljana	
Totals = 5	21	21	103'814	21	21	11

2.2 Weather data sources

To enable use of consistent, complete, detailed and readily available weather data, the simulation data from the global weather model NEMS30 (NEMS global) was used: they are available for any place on Earth in hourly steps, with multiple variables (air temperature, relative humidity, Wind speed, radiation, sunshine hours, precipitation, daytime hours, see Table 2.2) which are all consistently calculated for all places and updated daily (see https://content.meteoblue.com/en/specifications/weather-model-theory).

This approach enables more consistent and faster accessible data than the use of measurements, which are locally more precise, but not available for all locations and variables considered.

Table 2.2: Overview of weather data variables (air temperature, relative humidity, Wind speed, radiation, sunshine hours, precipitation, daytime hours). Source: NEMS30, meteoblue.com.

Variable	Unit	Reference	Aggregations	Comments
Air temperature	°C	@ 2m height	Daily Mean	Daily Min, Max possible
Relative humidity	%	@ 2m height	Daily Mean	Daily Min, Max possible
Wind speed	km/h	@ 10m height	Daily Mean	Daily Min, Max possible
Radiation	W/ m^{-2}	surface	Daily Sum	
Sunshine hours	hours	surface	Daily Sum	
Precipitation	mm	surface	Daily Sum	

The daily aggregations are calculated from hourly weather data. For ease of calculation, the daily aggregations have been calculated in UTC (Universal Time Convention) Greenwich time, leading to some differences of maximal 10 hours for distant times zones (Australia = -11, California = +8 hours). This difference is not expected to result in large effects, given the delay in response from the infection time to the manifestation of symptoms, the imperfect determination of the actual infection time, and the other influencing factors. Also, the aim of this study to find strong effects, which will not be masked by small time shifts.

The study covered all major climate zones and temperature ranges (see Figure 2.1).

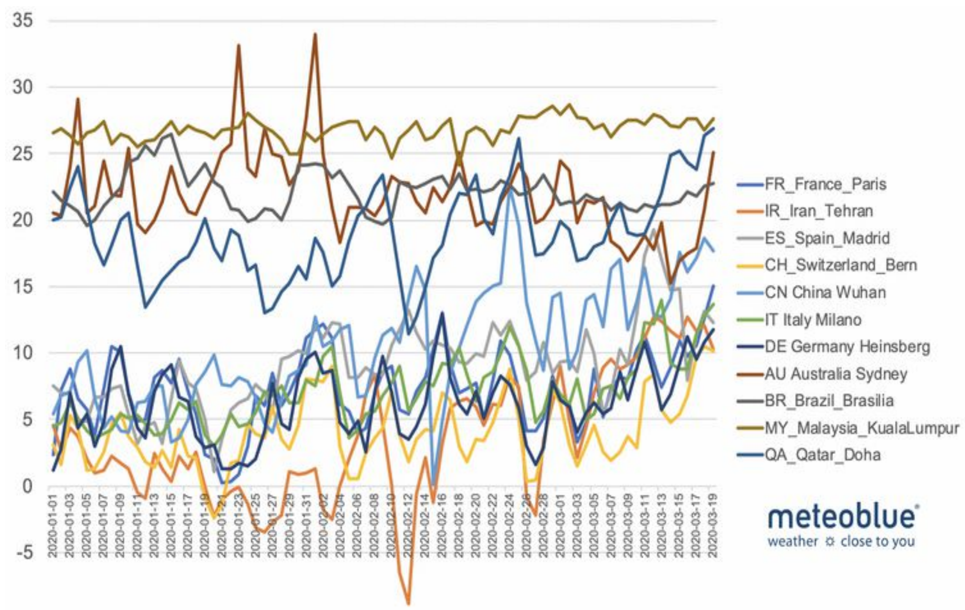


Figure 2.1: Daily mean air temperatures of selected countries; 11 countries, 4 continents, 02020-01-01 -03-18.

2.3 Evaluations

The correlations of daily new infections with weather data were calculated for the daily new infections with the daily weather variable aggregations (Daily Mean Temp, Mean Humidity, Mean Wind speed, Daily Sum Radiation, Sum Precipitation, Sum Sunshine, Sum Daylight) determined for the day of detection, and for 7 days before the registered infection date. This accounts for the estimated incubation period of 5-7 days.
To normalise the data, we calculated in a second step the daily growth rate of detections (see chapter 5) for the selected countries with sufficient cases (See Table 2.1)
Further, we averaged this growth rate over the 7 preceding days, to minimise the effect of delayed or weekend reporting (see chapter 5).

A further refinement would be possible by calculation of correlations for 10, 5, 3 and 1 days before symptom detection.

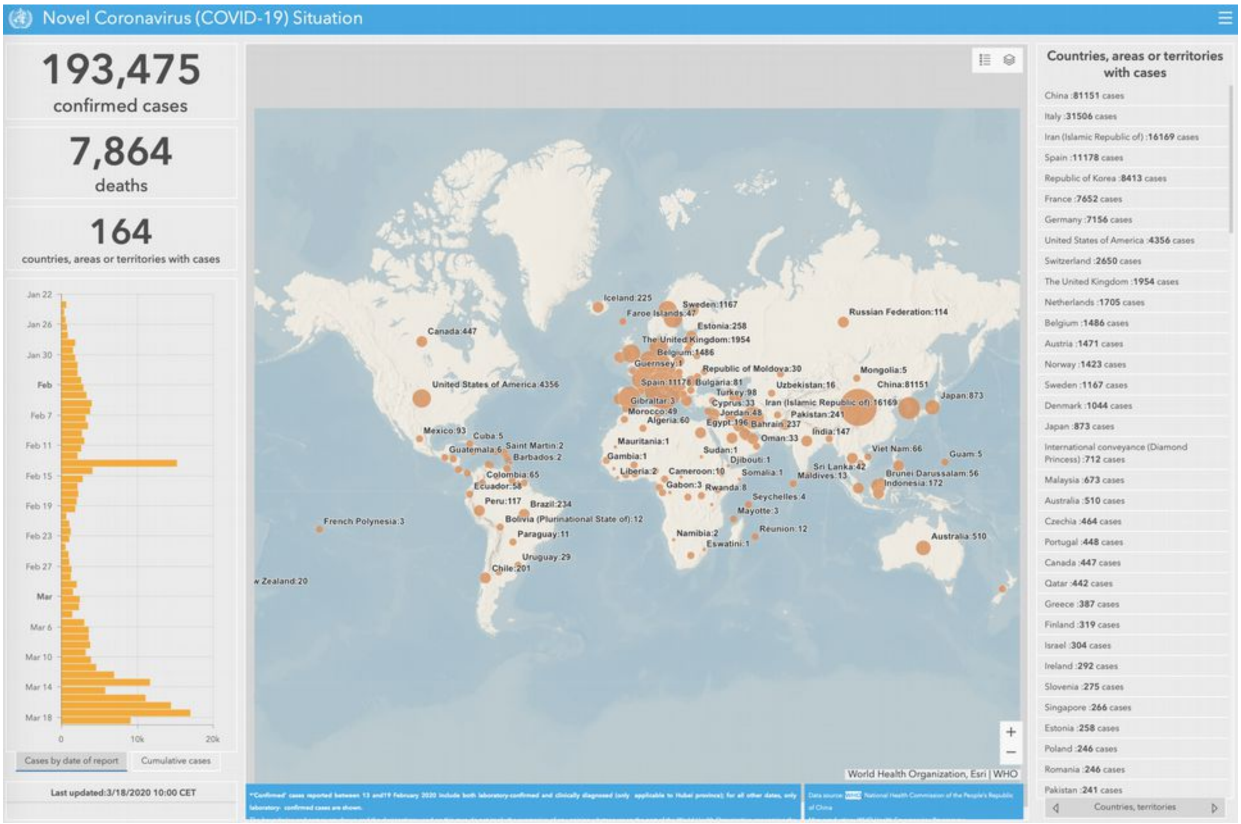


Figure 2.2: Map of current Corona-Virus infections. Status 18.03.2020, Source: WHO.

3 Results for all 21 countries

3.1 Air temperature

There is no significant correlation between the outside air temperature at the time of COVID-19 detection and the number of new detected cases (see Figure 3.1). This provides only a first indication of any potential effects, since meteorological conditions are of interest at the time of infection, which occurs typically 7-10 days before detection. These correlations will be analysed more in detail in Chapter 4.

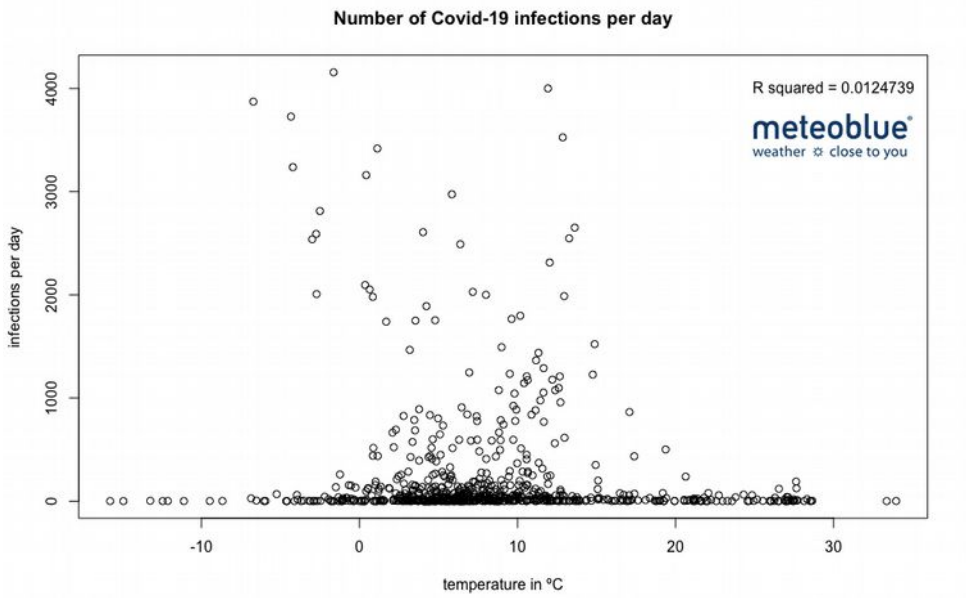


Figure 3.1: COVID-19 detections versus average air temperature on detection day; 21 countries, 02020-01-01 -03-18.

3.2 Relative humidity

For relative humidity of the air, the correlation with COVID-19 detection numbers is also nil (see Figure 3.2). Correlation with detection and infections is further analysed in Chapter 4.

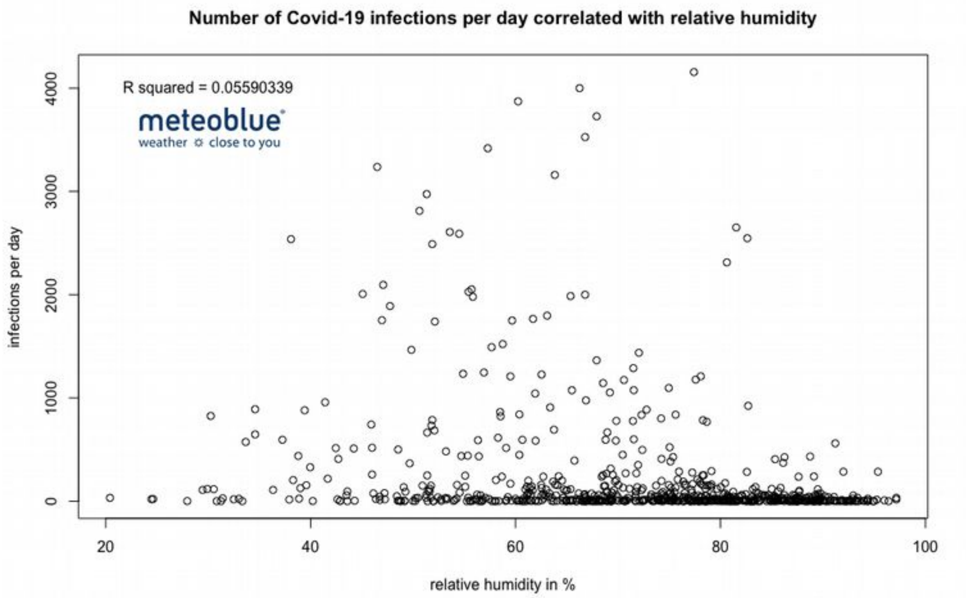


Figure 3.2: COVID-19 detections versus average air humidity on detection day; 21 countries, 02020-01-01 -03-18.

3.3 Wind speed

The correlation of COVID-19 detection numbers with windspeed on the day of detection is nil (see Figure 3.3). Correlation with detection and infections is further analysed in Chapter 4.

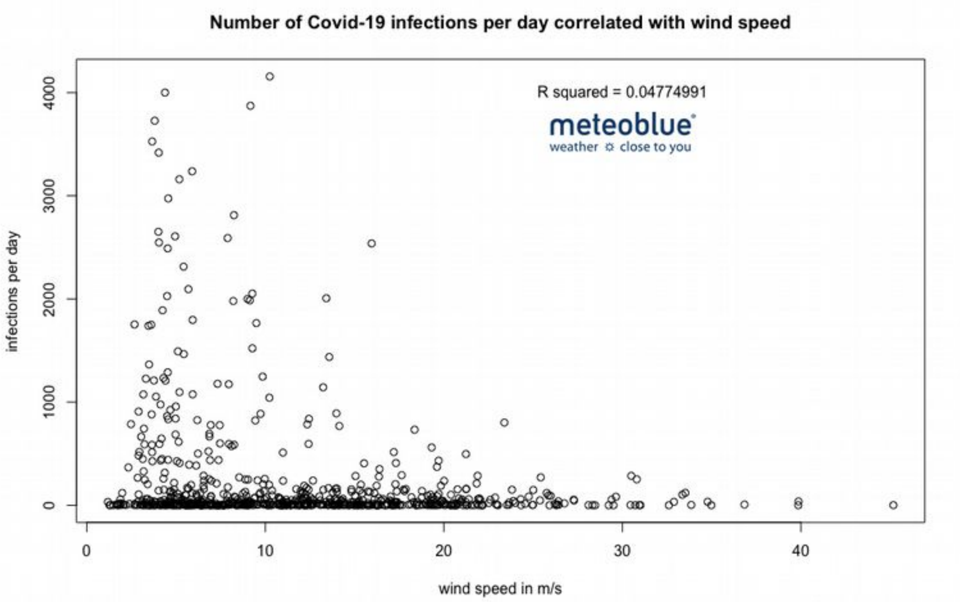


Figure 3.3: COVID-19 detections versus average air temperature on detection day; 21 countries, 02020-01-01 -03-18.

3.4 Radiation

There is no correlation of COVID-19 detection numbers with radiation sum on the day of detection (see Figure 3.4).

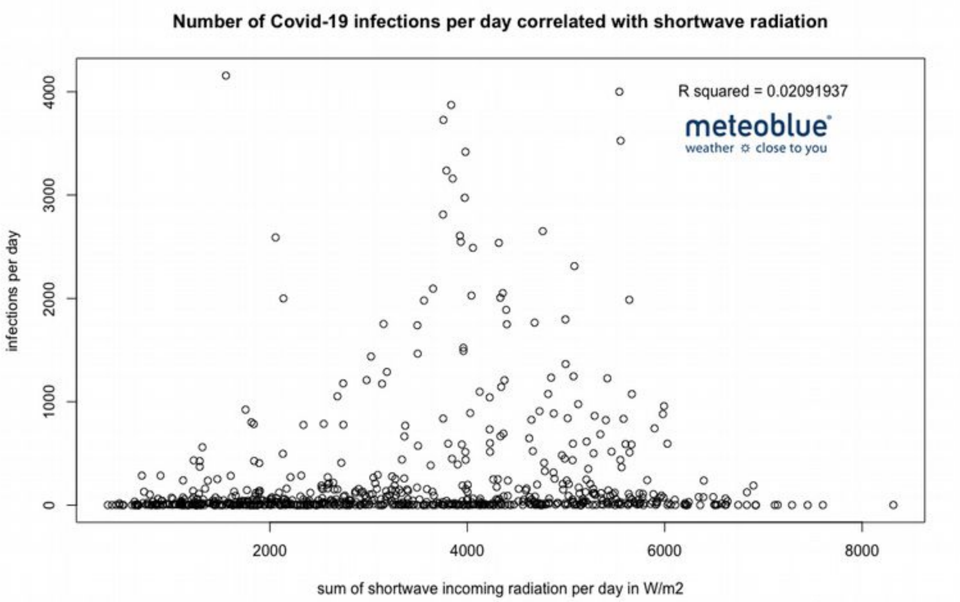


Figure 3.4: COVID-19 detections versus average air temperature on detection day; 21 countries, 02020-01-01 -03-18.

3.5 Sunshine hours

There is also no correlation of COVID-19 detection numbers with sunshine hours on the day of detection (see Figure 3.5). Further analysis follows in Chapter 4.

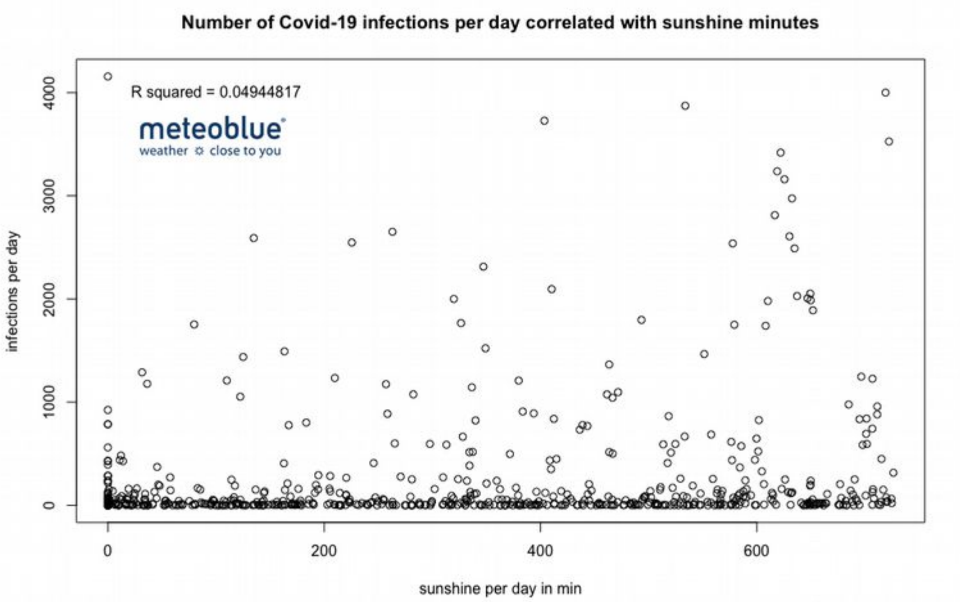


Figure 3.5: COVID-19 detections versus average air temperature on detection day; 21 countries, 02020-01-01 -03-18.

3.6 Precipitation

No correlation of COVID-19 detection numbers with precipitation sum on the day of detection could be found (see Figure 3.6).

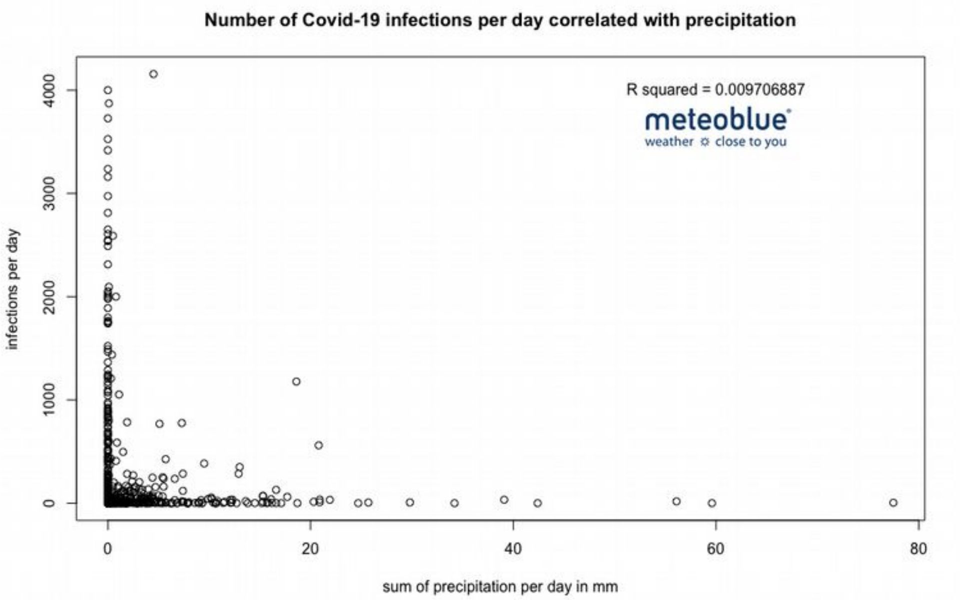


Figure 3.6: COVID-19 detections versus average air temperature on detection day; 21 countries, 02020-01-01 -03-18.

3.7 Summary

In summary, no correlations could be found for any of the weather variables. To further investigate possible correlations with detection and infections, a more detailed analysis is done for the 7 countries with higher number of cases (see Chapter 4).

4 Results for seven selected countries

4.1 Air temperature

There was no significant correlation between the outside air temperature at the time of COVID-19 detection and the number of new detected cases (see Figure 4.1.1). The correlation deteriorates to almost nil if the temperature 7 days before detection is considered (see Figure 4.1.2).

Since it is generally known that influenza development proceeds after infection without significant influence of meteorological conditions, the results for other variables will only be shown for 7 days before detection.

The correlations between air temperature at the time of COVID-19 detection and the number of new detected cases can therefore be considered artificial: some of it seems related to the rapid evolution in France and Iran at the some time of spring outbreak.

Figure 4.1.1: Plot of COVID-19 detections relative to average air temperature at the day of detection; 7 countries, period 2020-01-01 to 2020-03-18.

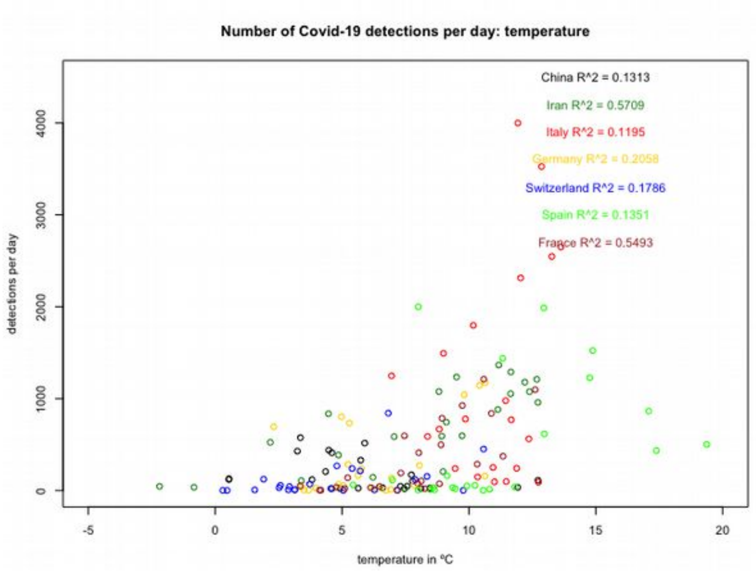
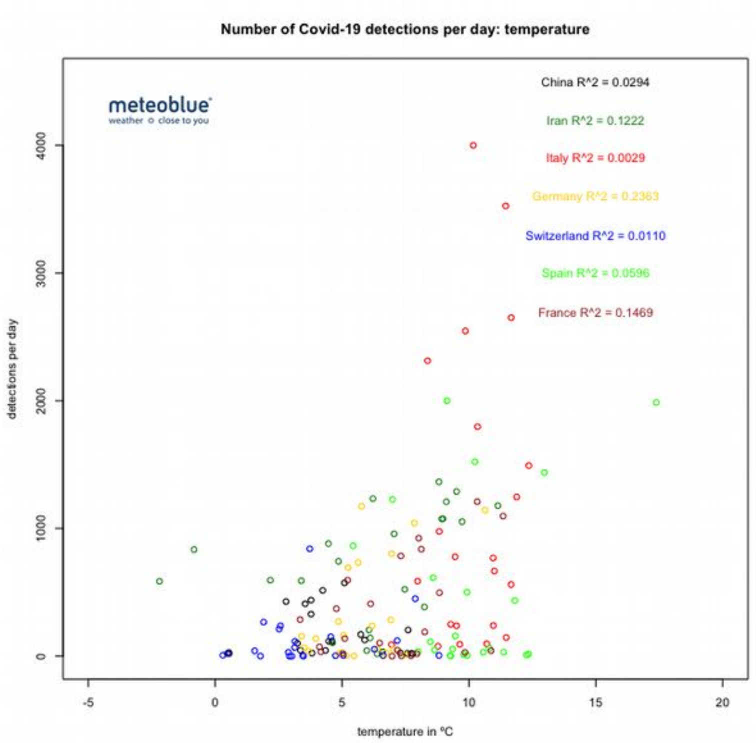


Figure 4.1.2: Plot of COVID-19 detections relative to average air temperature, seven days before detection; 7 countries, period 2020-01-01 to 2020-03-18.



4.2 Relative humidity

There is no significant correlation in any of the 7 countries between the outside air relative humidity seven days before COVID-19 detection and the number of new detected cases (see Figure 4.2).

Although it is to be expected that high air humidity increases the likelihood of Virus survival on surfaces (Günter Kampf, et al.), this does not seem to translate into significantly more infections. Also, the decrease in infections with higher temperatures observed by Jingyuan Wang at al. (2020) is not visible in these results, suggesting that other factors (concurrence of developments, containment measures, etc.) were responsible for such effects .

Further more detailed samples are necessary for determining possible effects.

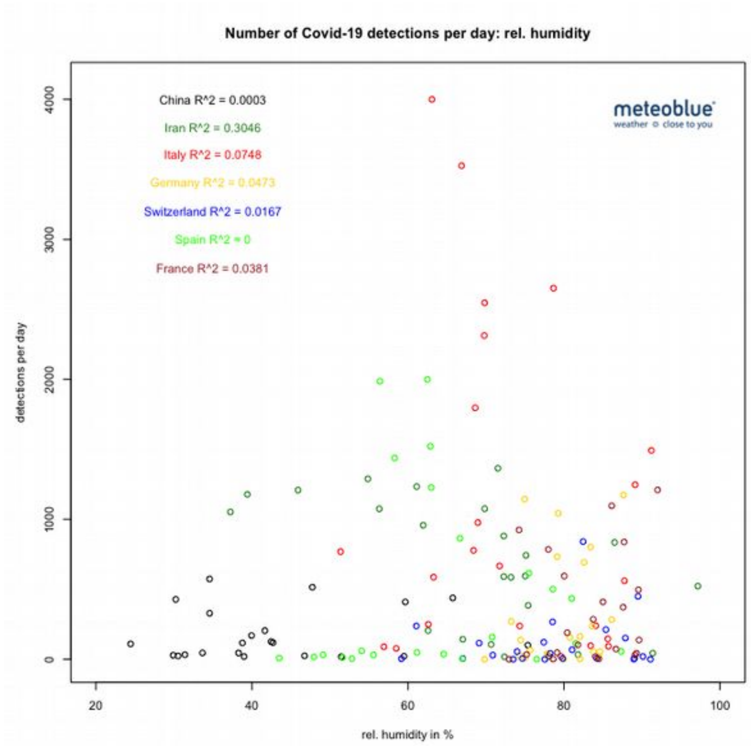


Figure 4.2: Plot of COVID-19 detections relative to air relative humidity (%) seven days before detection; 7 countries, period 2020-01-01 to 2020-03-18.

4.3 Wind speed

There is absolutely no correlation between the windspeed seven days before COVID-19 detection and number of new detected cases (see Figure 4.3).

A correlation was not to be expected, since wind speed affects people only when they are outside (whereas temperature and relative humidity have some effect on indoor environments and behaviour), so no further analysis is seems warranted on this variable.

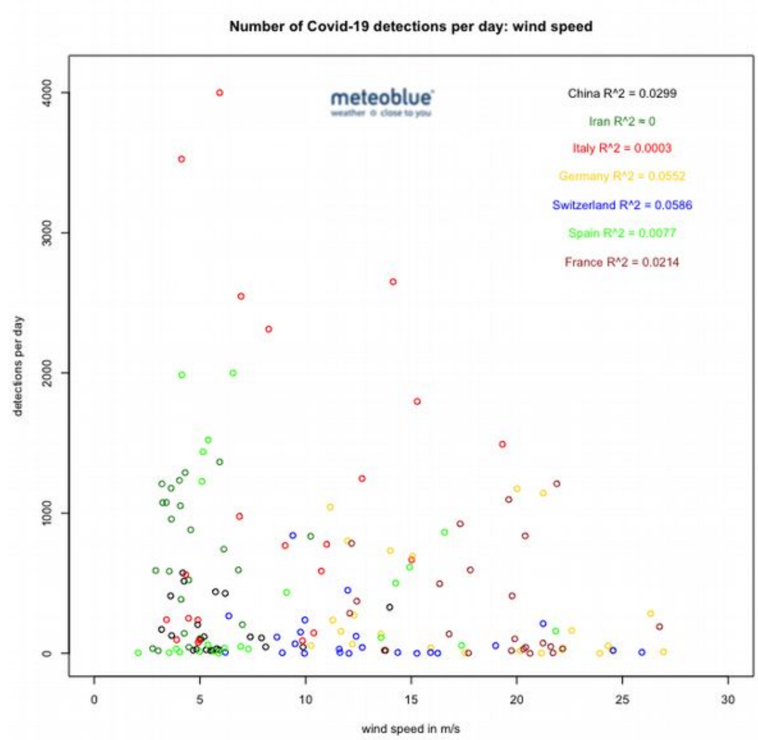


Figure 4.3: Plot of COVID-19 detections relative to average windspeed (m/s), seven days before detection. 7 countries, period 2020-01-01 to 2020-03-18.

4.4 Radiation

There is no correlation between the radiation sum seven days before COVID-19 detection and the number of new detected cases (see Figure 4.4).

Some correlation might be expected, since radiation may affects virus survival on surfaces outdoors, as well as people behaviour, but there is no indication of any effects, so further analysis would have to be done with much more spatially and temporally detailed samples on this variable.

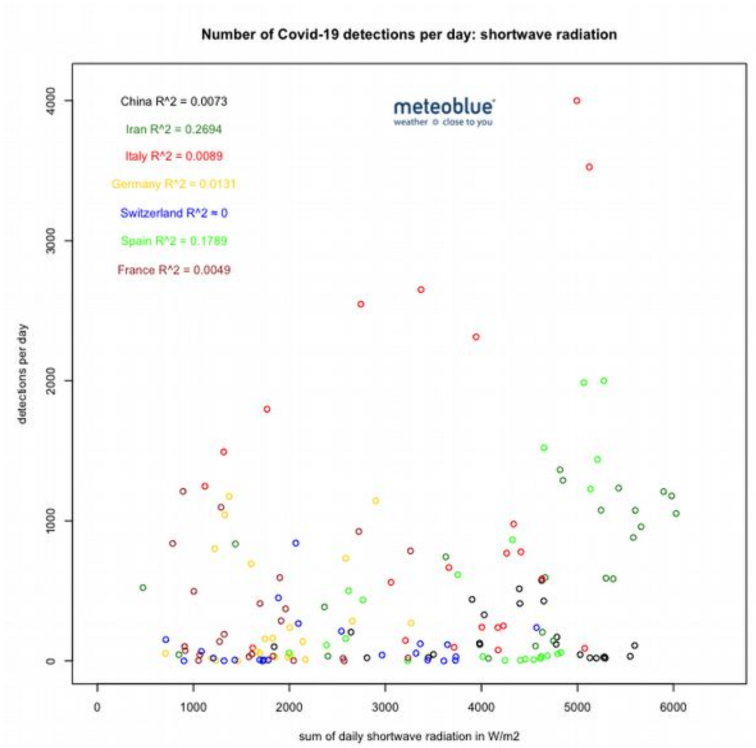


Figure 4.4: Plot of COVID-19 detections relative to total radiation (W/m^{-2}); seven days before detection. 7 countries, period 2020-01-01 to 2020-03-18.

4.5 Sunshine hours

There is absolutely no correlation between the sunshine hours seven days before COVID-19 detection and the number of new detected cases (see Figure 4.5).

Some correlation might be expected, since sunshine hours may affects virus survival on surfaces outdoors, as well as people behaviour, but there is no indication of any such effects, so no further analysis seems warranted on this variable.

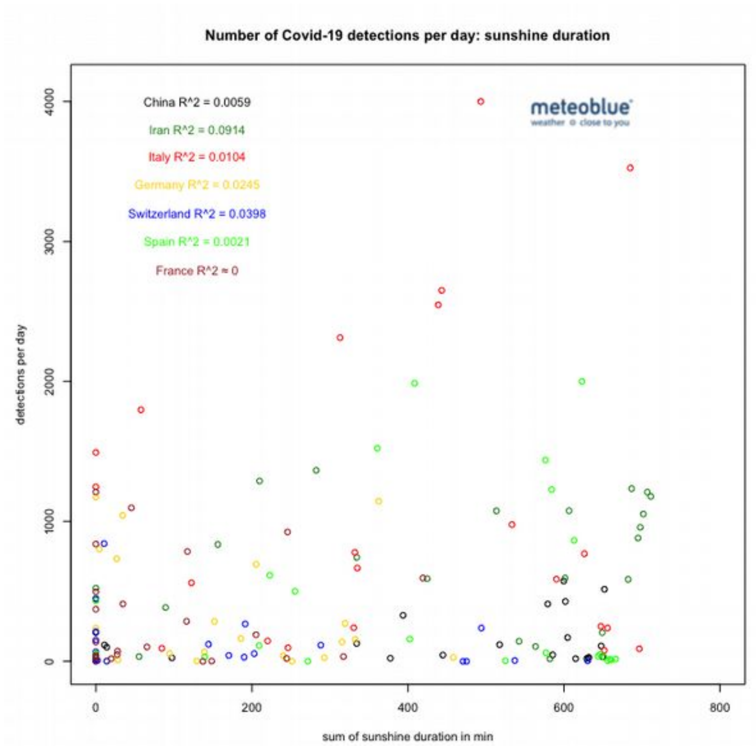


Figure 4.5: Plot of COVID-19 detections relative to daily sunshine hours ; seven days before detection. 7 countries, period 2020-01-01 to 2020-03-18.

4.6 Precipitation

There is no correlation between the precipitation sum seven days before COVID-19 detection and the number of new detected cases (see Figure 4.6).

A correlation was not to be expected, since precipitation affects people only when they are outside. Any effect on air moisture would have been visible through the analysis of relative humidity. Any effect on people behaviour is likely to surface in the analysis of radiation or temperature. Therefore, no further analysis seems warranted on precipitation.

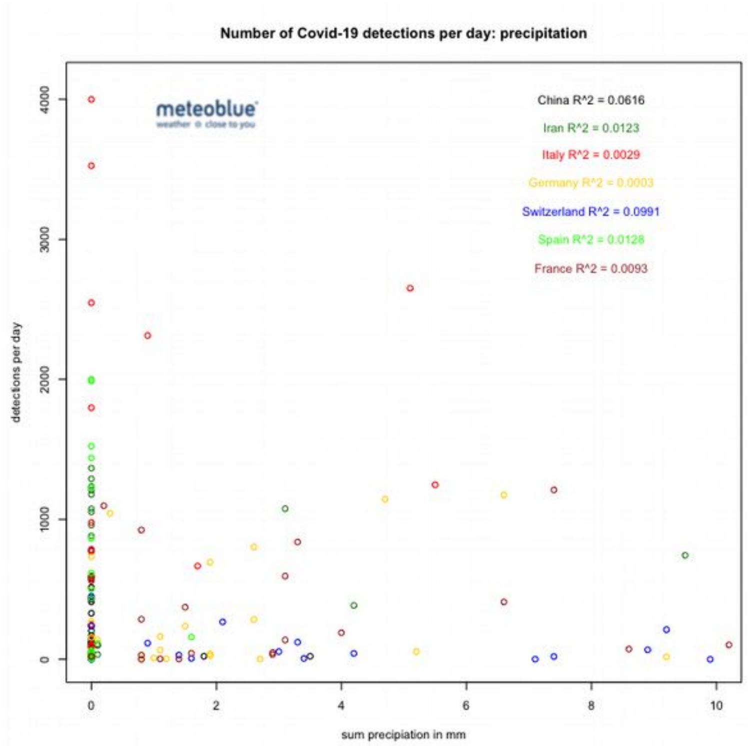


Figure 4.6: Plot of COVID-19 detections relative to daily precipitation (mm); seven days before detection. 7 countries, period 2020-01-01 to 2020-03-18.

4.7 Summary

The analysis of correlation between COVID-19 detection and 6 weather variables produced no visible correlations for any of the variables, neither in 21 countries from 5 continents and all global climate zones, with a total of 103'814 cases, nor in a selected number of 7 countries from Asia and Europe, with a total of 76'761 cases.

Some indications of possible correlations were found for :

- Air temperature : there may be an effect, but this remains to be further analysed.
- Relative humidity: possible hypothesis are effects on parameters such as Virus survival on surfaces, longevity of infected droplets in the air, and people behaviour would require analysis on much more detailed datasets.
- Radiation: effects on virus survival on outdoor surfaces, as well as people behaviour, would need to be done with much more spatially and temporally detailed samples .

For the variables wind speed, sunshine hours and precipitation, no further analysis of correlation with COVID-19 infections seems warranted.

Several methodology problems do still have to be addressed, as shown in Table 4.1. Some of these are addressed in section 5.

Table 4.1: Overview of methodology problems to be addressed.

Effect	Example	Possible solution
Effect of coincidence	Rising temperatures in spring along with rising infections	Compare countries with different climate (See section 5)
Changes in behaviour	Public restrictions, Hygiene measures,	Compare countries with different climate in the early (unrestricted) phase (section 5)
Reporting imprecision	Different and changed detection methods, delay in reporting,	Larger samples, Select countries with similar conditions

5 Results for eleven selected countries

Based on the interim results, we refined the analysis by normalising the data for daily growth rate of detections, and averaged the growth rate over the previous seven days, to eliminate weekday and other effects of reporting. We then included 4 countries from the warm climates (seeFigure 2.2), which had sufficient cases for a significant analysis (Table 2.1), to obtain a better spread of climate zones and temperatures during the infection period. The results are presented in the following.

5.1 Air temperature

There is no significant correlation between the outside air temperature on the day of COVID-19 detection and the average growth rate of the previous 7 days in any of the 11 countries (see Figure 5.1). The correlation deteriorates to nil if the temperature 7 days before detection is considered (see Figure 5.1.2).

Neither are the correlations significant within a country, nor is there any visible trend-line across countries (as shown also Figure 3.1).

Significant containment measures have been implemented in China, but also the other countries without significant containment measures during the study period (Italy, France, Germany, Brazil, Australia), and we are seeing very similar growth rates under a wider range of air temperatures .

Based on these data, there is no evidence that the growth of COVID-19 infections is subject to significant air temperature influence in the range between 0 and 30°C, different from what is known for influenza (Lowen et al 2014, Van Noort et al 2012).

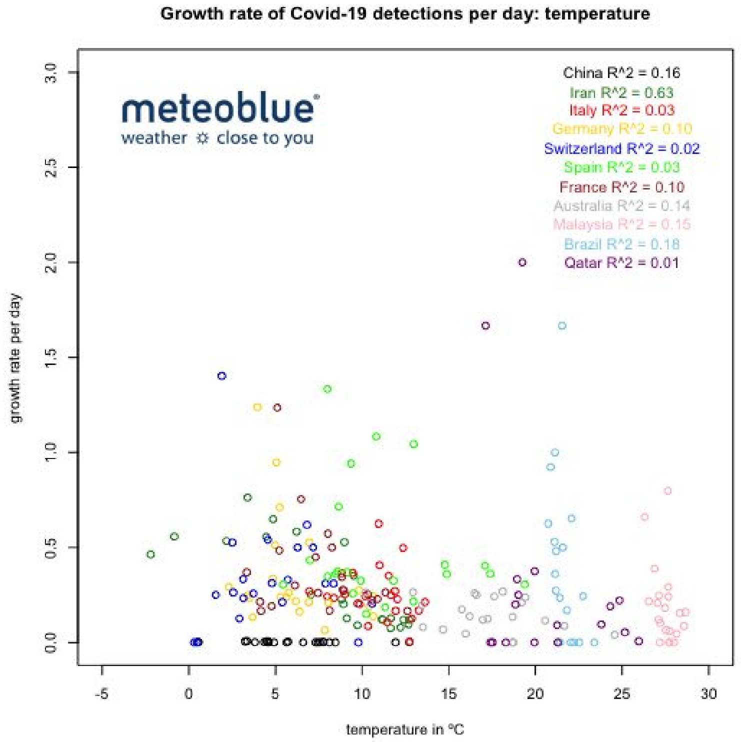


Figure 5.1.1: Growth of COVID-19 detections (7-day average) relative to air temperature on detection day; 11 countries, period 2020-01-01 - 2020-03-18.

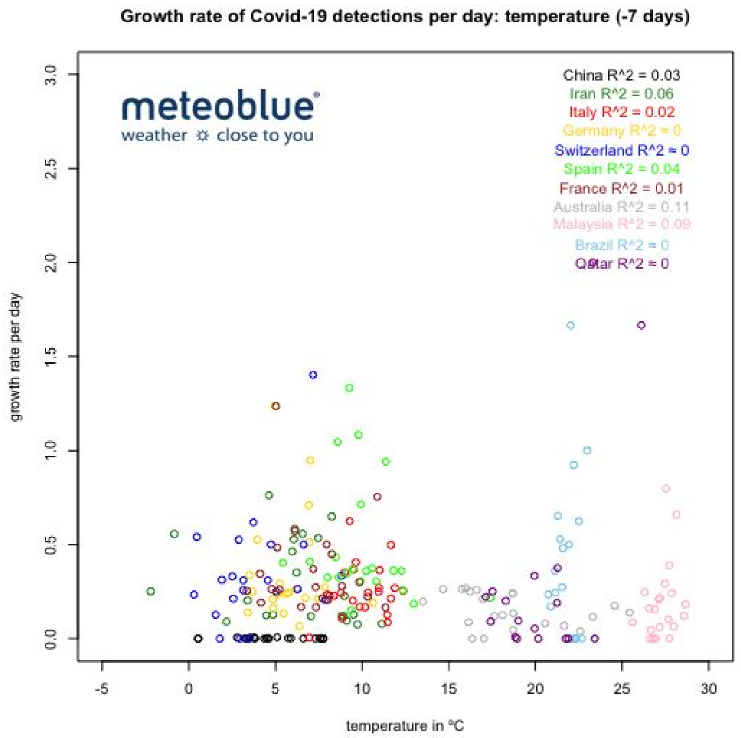


Figure 5.1.2.: Growth of COVID-19 detections (7-day average) relative to air temperature 7 days before detection; 11 countries, period 2020-01-01 to 2020-03-18.

5.2 Relative humidity

There is no significant correlation in any of the 11 countries between the outside air relative humidity on the day of COVID-19 detection and last 7-day case growth rate (see Figure 5.2).

It is known that high air humidity increases the likelihood of Virus infections (Lowen et al 2014), and this is actually translating into higher growth rates in conditions with more than 60% relative air humidity.

These results indicate that countries with moist climate will see more rapid spread of COVID-19 infections than countries with very dry climate.

Further more detailed samples are necessary for determining possible effects.

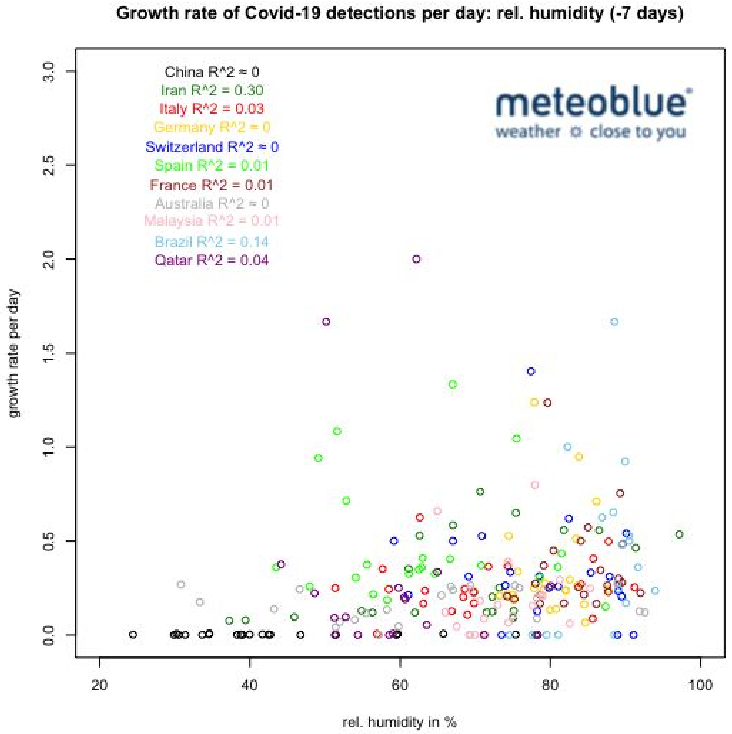


Figure 5.2: Growth of COVID-19 detections (7-day average) relative to air relative humidity (%) 7 days before detection; 11 countries, period 2020-01-01 - 2020-03-18.

5.3 Wind speed

There is absolutely no correlation between the windspeed on the day of COVID-19 detection and last 7-day case growth rate (see Figure 5.3).

A correlation was not to be expected, since wind speed affects people only when they are outside (whereas temperature and relative humidity have some effect on indoor environments and behaviour), so no further analysis is warranted on this variable.

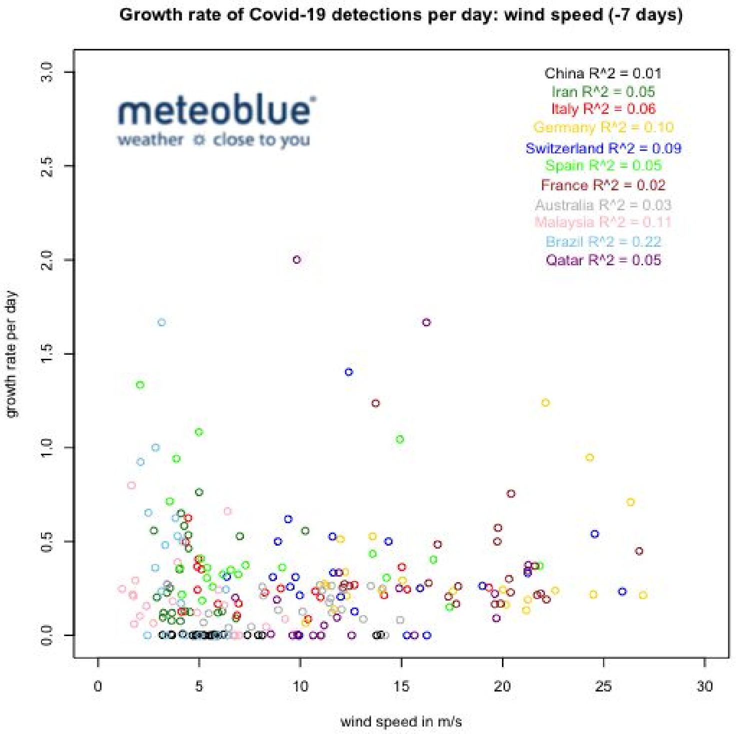


Figure 5.3: Growth of COVID-19 detections (7-day average) relative to average windspeed (m/s) 7 days before detection; 11 countries, period 2020-01-01 - 2020-03-18.

5.4 Radiation

There is no correlation between the radiation sum on the day of COVID-19 detection and the average growth rate of the previous 7 days in any of the 11 countries (see Figure 5.4).

Although some correlation might be expected, due to since radiation effect on virus survival on surfaces outdoors, as well as on people behaviour, there is no indication of any effects.

Further analysis would have to be done with much more spatially and temporally detailed samples on this variable, and does not warrant much focus relative to other variables.

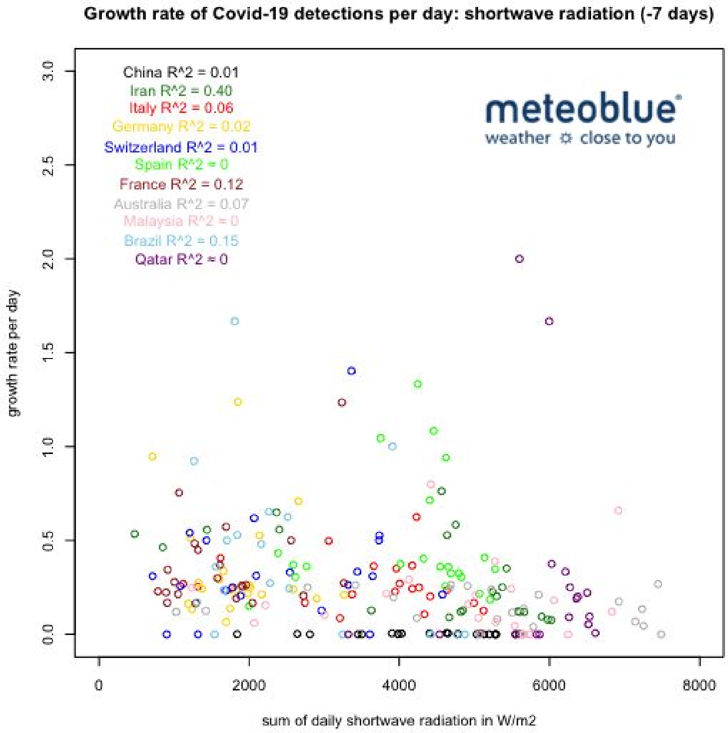


Figure 5.4: Growth of COVID-19 detections (7-day average) relative to total radiation (W/m^2) 7 days before detection; 11 countries, period 2020-01-01 - 2020-03-18.

5.5 Sunshine hours

There is absolutely no correlation between the sunshine hours on the day of COVID-19 detection and the average growth rate of the previous 7 days (see Figure 5.5).

Any effects of sunshine would rather translate into temperature, relative humidity or people behaviour.

No further analysis is warranted on this variable at this stage.

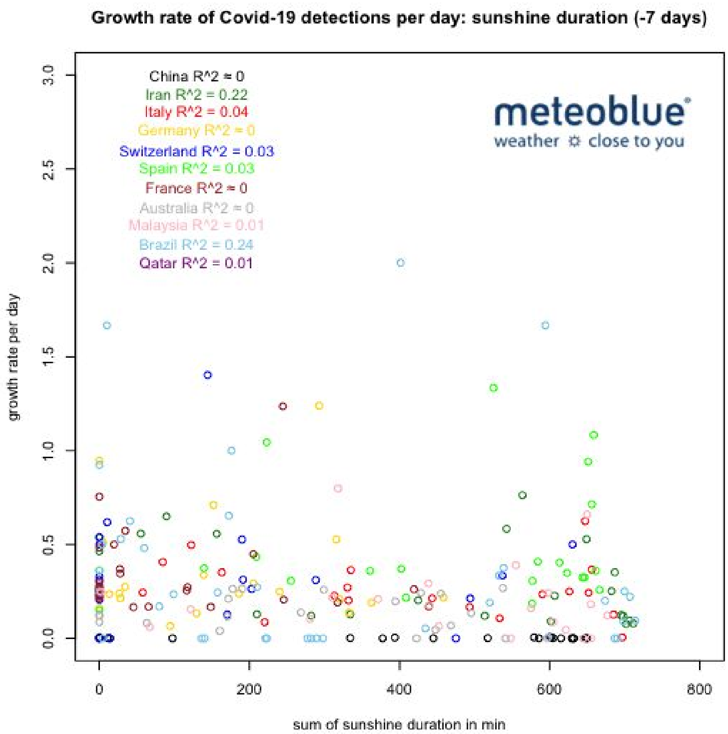


Figure 5.5: Growth of COVID-19 detections (7-day average) relative to sunshine hours 7 days before detection; 11 countries, period 2020-01-01 - 2020-03-18.

5.6 Precipitation

There is no correlation between the precipitation sum on the day of COVID-19 detection and the average growth rate of the previous 7 days (see Figure 5.6).

An effect on air moisture would have been visible through the analysis of relative humidity. Any effect on people behaviour is likely to surface in the analysis of radiation or temperature. Therefore, no further analysis is warranted on precipitation.

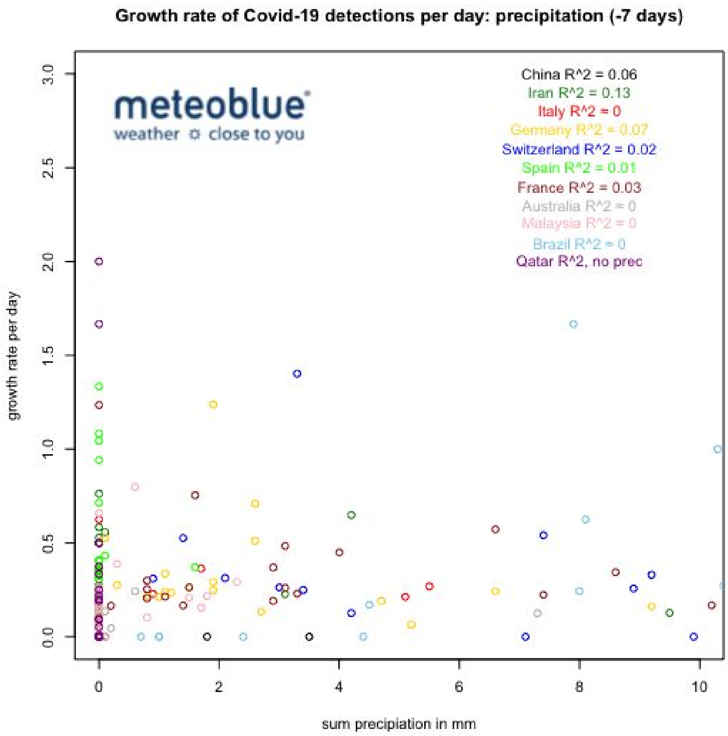


Figure 5.6: Growth of COVID-19 detections (7-day average) relative to daily precipitation (mm) 7 days before detection; 11 countries, period 2020-01-01 - 2020-03-18.

5.7 Summary

The analysis of correlation between COVID-19 average growth rate of the previous 7 days and 6 weather variables produced no visible correlations for most of the variables, in 11 countries from 4 continents and all global climate zones, with a total of 78'128 cases, nor in a selected number of 7 countries from Asia and Europe, with a total of 76'761 cases.

Some indications of possible correlations were found for :

- Air temperature : there may be a slight effect, but describing it would requires much more detail analysis, given the many other influencing factors.
- Relative humidity: higher humidity seems to lead to higher COVID-19 infection rates. Possible reasons are effects on parameters such as Virus survival on surfaces, longevity of infected droplets in the air, and people behaviour, and would require analysis on more detailed datasets.
- Radiation: possible effects on virus survival on outdoor surfaces, as well as people behaviour, are not visible from this study and would need to be done with much more spatially and temporally detailed samples .

For the variables wind speed, sunshine hours and precipitation, no further analysis of correlation with COVID-19 infections seems warranted.

Several methodology problems do still have to be addressed, as shown in Table 5.1.

Table 5.1: Overview of further methodology problems to be addressed.

Effect	Example	Possible solution
Effect of coincidence	Rising temperatures in spring along with rising infections	Compare more locations with different climate
Changes in behaviour	Public restrictions, Hygiene measures,	Segment countries into groups with different restriction regimes and timings
Reporting imprecision	Different and changed detection methods, delay in reporting,	Larger samples, Adjustments for sampling methods Select countries with similar conditions More localised detection data.

6 Conclusions

This study showed no significant correlation between COVID-19 detection growth rate and any of 6 weather variables analysed (air temperature, relative humidity, radiation, wind speed, sunshine hours and precipitation).

Based on the significant sample (>100'000 cases, 21 countries, several climate zones), some important conclusions seem possible:

- Higher air temperatures are unlikely to slow the spread of the virus significantly. No evidence of delays were found in any of the countries with higher temperatures (Malaysia, Australia, Qatar, Brazil). Therefore, we can not rely on warmer climates or seasons to reduce the spread of COVID-19 infections,
- Relative humidity: there is a trend of increasing infection growth rate with increasing air relative humidity, as is it generally known for influenza types. Countries with low air humidity may therefore experience a slightly slower growth, but certainly not a containment of the disease.
- The COVID-19 infections seem to be largely independent of external weather influence, except a slight effect of .
- Further analysis should focus on the effect of temperature, relative humidity and radiation, by eliminating masking factors such as reporting imprecision and timing, movement between infection and detection, behaviour changes (public restrictions), and location differences.

As a general summary, it seems possible to conclude that containment of COVID-19 infections can not rely on weather as a significant factor in helping to reduce the spread of the disease.

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