Geospatial Data Analysis for Smart Communities

Effects of Covid 19 stringency measures on air quality in Switzerland

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Masters in applied information and Data Science

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29.12.2021

1. Introduction

On March 11th, 2020, the World Health Organization declared COVID-19 a global pandemic, indicating significant global spread of a new infectious disease [1]. At this point, there were 118,000 confirmed cases with the novel coronavirus SARS-CoV-2 in 110 countries.

To quell the pandemic, governments around the world put in place a number of restrictions, with different impacts on the world economy (*e.g.* factory closures, school closures, limitation of movement), as well as every individual person - to an extent that is seen only once in a century. The impact of the pandemic and its consequences are felt differently, depending on our status as individuals and as members of society. While some can more easily adapt to working online, home-schooling their children and ordering food for delivery, others have no choice, but to be potentially exposed while performing functions critical to society.

In this work, we explored the effects of the COVID-19 restrictions and the changes in working patterns - as a result of them - on the air quality in Switzerland through visualization.

As a relevant representative variable, we chose to focus our work on Particulate Matter 2.5 (PM2.5) measurements. This size of particles, also known as fine particles, are considered to pose the greatest risk to human health [2]. Most particles form in the atmosphere as a result of complex reactions of chemicals, such as sulfur dioxide and nitrogen oxides, which are pollutants emitted from power plants, various industries and automobiles.

It can be assumed that factory closures and home office mandates during the pandemic have led to significantly less traffic and industrial activity and therefore a reduction in the emission of PM2.5 should be observable.

As a comprehensive parameter to monitor the changes in COVID-19-related restrictions over time, researchers from Oxford University have created the COVID-19 Government Response Tracker (OxCGRT), which quantifies the stringency and policy measures of each country "based on nine response indicators including school closures, workplace closures, and travel bans, rescaled to a value from 0 to 100 (100 = strictest)" [3].

Utilizing monthly stringency data and PM2.5 measurements, this work illustrates the changes in local PM2.5 concentrations in Switzerland during the pandemic.

2. Materials and methods

Data

<u>Stringency data -</u> Oxford COVID-19 Government Response Tracker (OxCGRT). The average monthly stringency index was calculated using Python 3.6 and pandas and then plotted using matplotlib.

<u>Air quality data and precipitation -</u> Daily data on the concentration of PM2.5 in air and rain precipitation in mm from 14 different stations, which was collected by the National Air Pollution Monitoring Network (NABEL), was downloaded from the website of the federal office of environment Switzerland [4].

This data was used to build a simplified linear model using python 3.8 for the prediction of the monthly sum of PM2.5, based on location and precipitations. The model was validated using the data collected before any stringency measures (due to corona) were initiated in Switzerland (2016-2019). A prediction of the PM2.5 concentration in air for the years 2020-2021 was then performed, based on the model.

In the following stage, a calculation of the differences between the predicted concentration based on our model, and the real PM2.5 concentration measured at each station was carried out.

Map visualisation and layers

Map visualisation was done using QGIS 3.22.1.

The map contains the world map from open street map as a base raster layer and the Swiss country border polygon layer downloaded from the Federal Office of Topography [5].

A NABEL monitoring stations point layer was downloaded from the Federal Office of Topography [5]. The differences of the monthly PM2.5 concentrations, which were calculated for each monitoring station as described previously, was joined to the stations point layer with the existing attribute table.

Spatial interpolation of the change in PM2.5 concentration between the monitoring stations was calculated using the Inverse Distance Weighted (IDW) method and then visualized in QGIS for each month in a separate map. The individual maps were then bundled into an animated time lap gif using photoshop.

3. Results and discussion

In this work, we aimed to explore if the introduction of stringency measures in Switzerland during the COVID-19 pandemic have led to a reduction of PM2.5 concentrations in the air.

Figure 1 shows a comparison of the PM2.5 prediction model results on unseen validation data vs. the real PM2.5 concentration measured at the Rigi NABEL station during 2019. The model resulted in a RMSE score of 2.4019 and r^2 of 0.99831.

The average RMSE score calculated from the prediction results on the validation data from all 13 stations (one station was removed in the pre-processing stage due to missing data) is 2.485 with an average r^2 of 0.994.

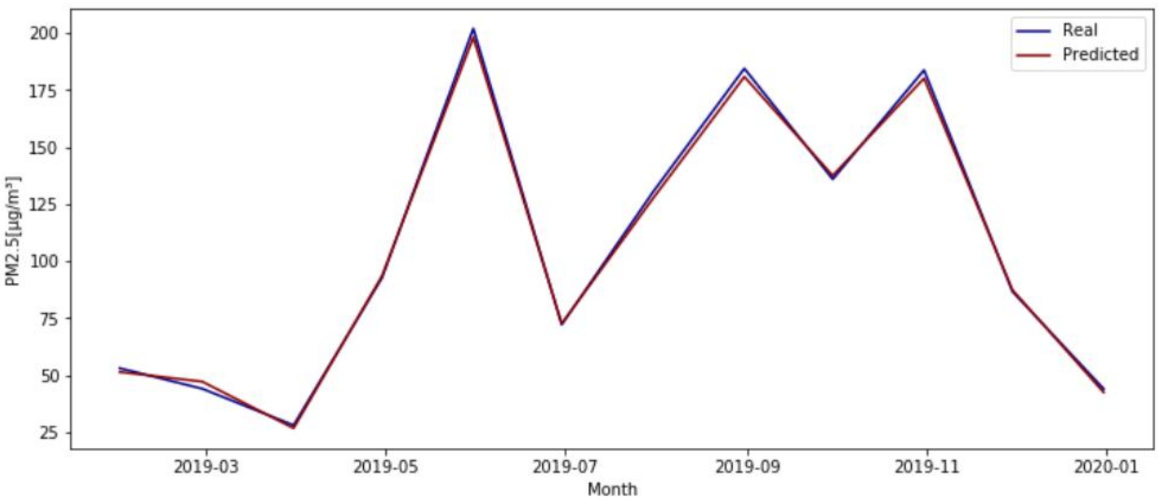

Fig.1: Rigi station PM2.5 concentration by month in validation data (pre-restrictions)- Real vs Predicted

Figure 2 shows the predicted PM2.5 values calculated from the model for the years 2020-2021 (with stringency measures) vs. the real values measured at the Rigi NABEL station. The RMSE score has decreased from 2.4 on the validation data to 9.17 on the predicted data from 2020-2021, while r^2 has decreased from 0.998 to 0.987 respectively. The figure shows a more significant difference between the predicted values and the real values measured in August 2020.

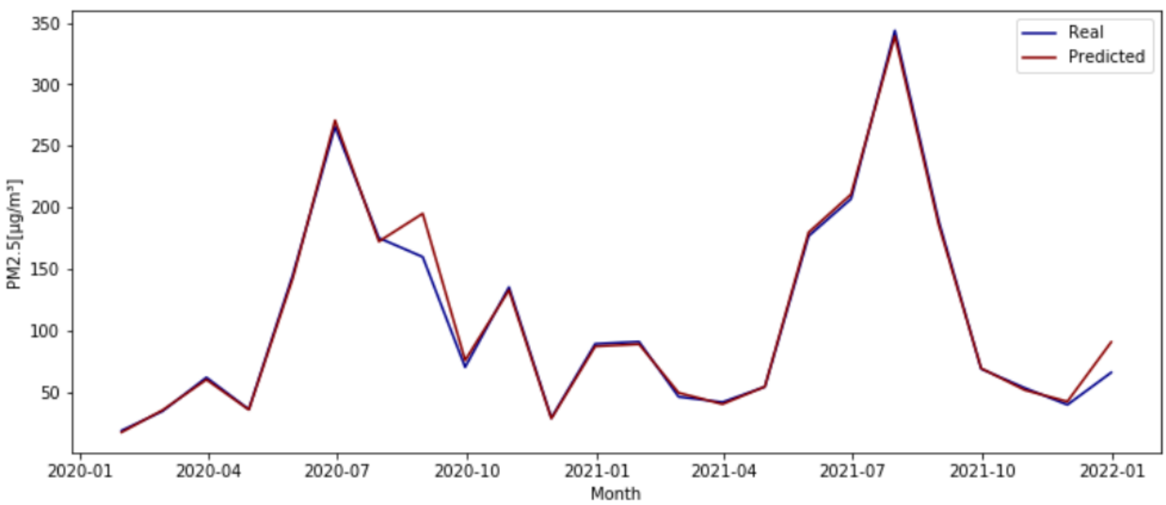

Fig.2: Rigi station PM2.5 concentration by month during the pandemic- Real vs Predicted

Figure 3 illustrates - using an animated map - the spatial interpolation of the difference between measured values of PM2.5 concentration and the predicted values by month for each NABEL station.

Herein, a blue colour shade represents lower values of PM2.5 at the measured station vs. the prediction. Red represents higher values at the measurement stations. No colour indicates that there is no significant change between the model and the real values (values within the RMSE score of validation data ± 2.5).

In addition, the average stringency index during the respective month is presented in the lower graph. Furthermore, the average stringency index and the number of days with a stringency index over 50 for the respective month, is presented in the upper right corner. The map for December 2021 was omitted from the results as data was still incomplete. The results for the PM2.5 sum for February 2020 may be misleading do to the difference in the number of days (29 days during February of the leap year 2020 instead of 28).

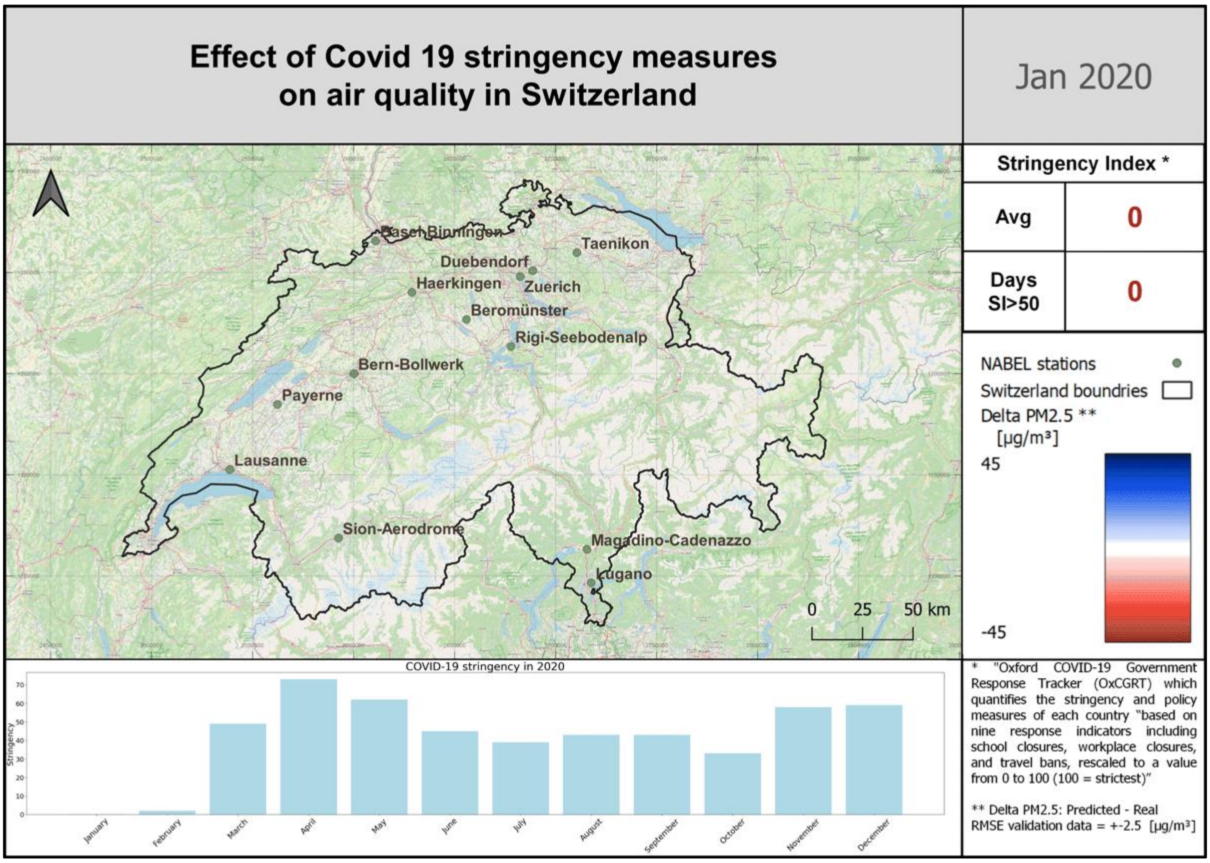

Fig.3: Animated map of spatial interpolation of PM2.5 differences between measured data and predicted data.

No significant impacts of the stringency measures on PM2.5 concentration can be observed from the map during the year 2020. Some localized reduction in PM2.5 concentration in June 2020 (see Fig. 4) can not be directly correlated to stringency measures. Similarly, a significant localized event at the Rigi station (Aug 2020, Fig. 3) and station Beromünster (July 2021, Fig. 3) can not be directly correlated to the stringency index of the respective months.

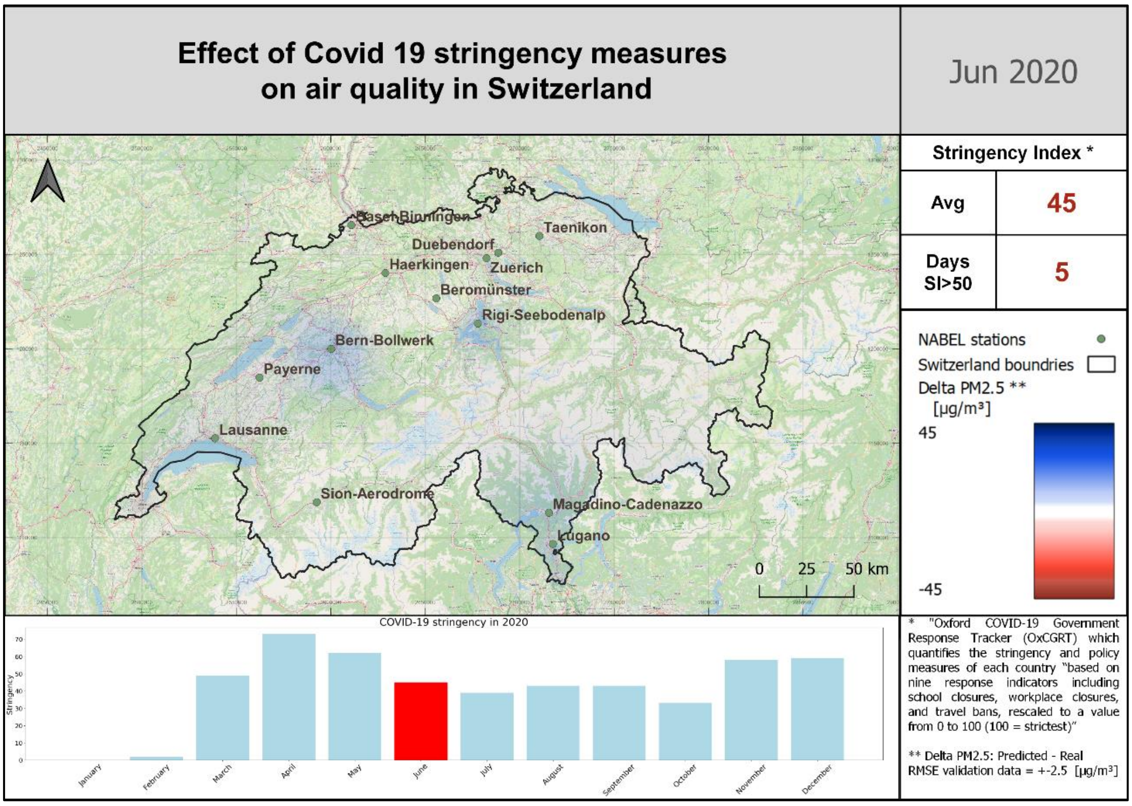

Fig.4: Map of spatial interpolation of PM2.5 differences between measured data and predicted data - June 2020.

A visible positive difference in PM2.5 between real measurements and predicted model can be observed for February 2021 (see Fig. 5). The decrease in PM2.5 concentration (in relationship to the model) is in line with the end of the second corona wave in Switzerland. Correspondingly, high stringency restrictions were implemented from November 2020 and the stringency index peaked in January 2021.

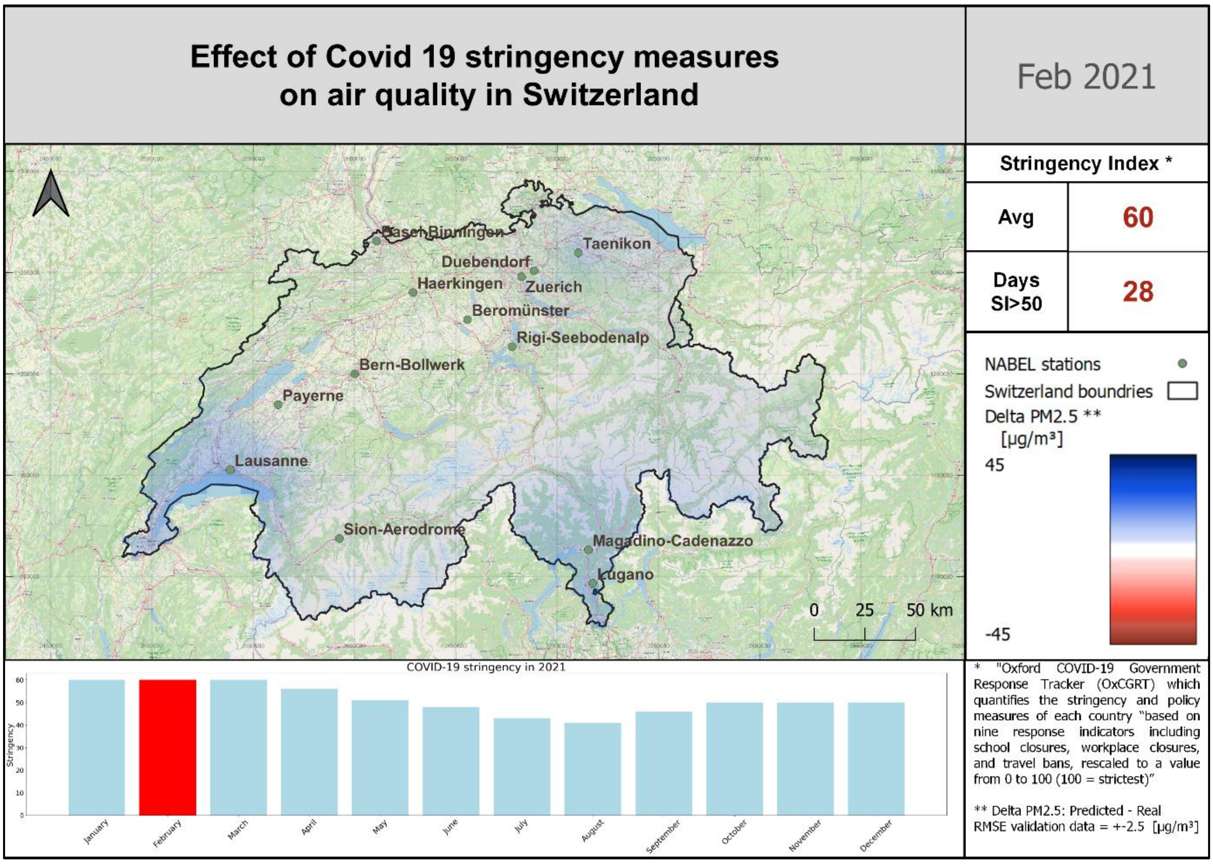

Fig.5: Map of spatial interpolation of PM2.5 differences between measured data and predicted data - February 2021.-

4. Conclusion

The herein presented data to illustrate effects of covid-related societal restrictions on the air pollution – more specifically PM2.5 as a representative value – has limited explanatory power. While a correlated effect of strict measures on the lowered concentration of PM2.5 can be observed in February 2021, other months coinciding with strict lockdowns do not show a reduced PM2.5 concentration, as would be expected (i.e. April 2020). Even though the stringency index for April 2020 was even higher than for February 2021, 73 and 60 respectively, a reduction of PM2.5 could only be observed for February 2021. It can be hypothesized that the length of strict measures during the second wave with increasing stringency over two months before its peak in January, showed a delayed effect on the PM2.5 concentration. In comparison, during April 2020, although stringency was high, the duration of the measures was significantly shorter.

More importantly, there are many environmental and other local influences on PM2.5 that could not be taken into consideration for the herein used model, due to the limited availability of corresponding data sets. Such factors could be winds, wildfires or other more complex and local events. Any addition of such influences to the model for the prediction of PM2.5 could improve the model accuracy and aid in illustrating deviations between model and measured values as an effect of covid-related shut-downs and other measures.

While other studies have proven the reduction of air pollution during COVID-related lockdowns for different areas of the world, these studies referred to more narrow time-frames with daily value comparisons instead of monthly averages [6].
Moreover, it can be said that Switzerland – throughout the pandemic – has had more lenient restrictions than other countries, as can also be seen by the stringency index. The highest value for Switzerland was 73 in April 2020, while several countries were at the highest value of 100 (e.g. India).

5. Appendix

Old version of the animated map, based on the original project concept design - Median PM2.5 concentration in reference years (2017-2019) minus concentration in each month for the years 2020 and 2021. The data showed inconsistencies in the results (i.e. large variance in results for month with high stringency and low stringency) which led us to applying the prediction model, to achieve a better representation of the air pollution differences.

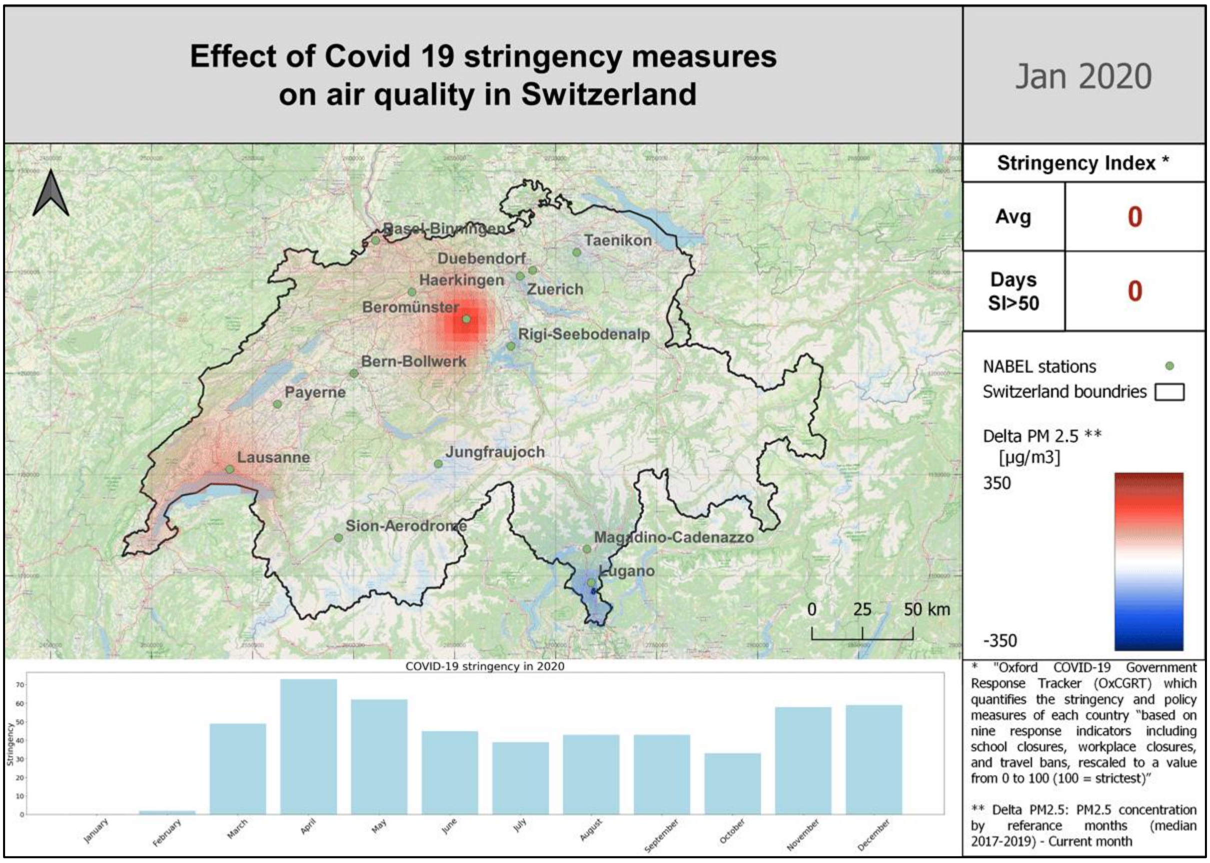

Fig.6: Animated map of spatial interpolation of PM2.5 differences between reference data and measured data.

References:

[1] World Health Organization (2020). World Health Organization Coronavirus Update. Retrieved June 7, 2021 from: https://www.who.int/emergencies/diseases/novel-coronavirus-2019

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[3] Oxford COVID-19 Government Response Tracker. Retrieved December 3, 2021 from https://ourworldindata.org/grapher/covid-stringency-index

[4] Federal Office for the Environment FOEN. Retrieved December 3, 2021 from: https://www.bafu.admin.ch/bafu/en/home/topics/air/state/data/data-query-nabel.html

[5] Federal Office of Topography swisstopo. Retrieved December 3, 2021 from:

Map.geo.admin.ch

[6] COVID-19 lockdowns cause global air pollution declines. Zander S. Venter, Kristin Aunan, Sourangsu Chowdhury, Jos Lelieveld. Proceedings of the National Academy of Sciences Aug 2020, 117 (32) 18984-18990; DOI: 10.1073/pnas.2006853117