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Supplementary Information for

Higher airborne pollen concentrations correlated with increased SARS-CoV-2 infection rates, as evidenced from 31 countries across the globe

Athanasios Damialis[1*+], Stefanie Gilles[1+], Mikhail Sofiev[2], Viktoria Sofieva[2], Franziska Kolek[1], Daniela Bayr[1], Maria P. Plaza[1], Vivien Leier-Wirtz[1], Sigrid Kaschuba[1], Lewis H. Ziska[3], Leonard Bielory[4,5,6], László Makra[7], Manuel Mar Trigo[8], COVID-19/POLLEN study group[#], Claudia Traidl-Hoffmann[1]

* Athanasios Damialis
Email: thanos.damialis@tum.de

+ : Equally contributed
# : The list of co-authors (and their full affiliations) is attached to the manuscript as a separate file. Their details, nonetheless, have been included in the submission platform. The full author list (154 in total) will be integrated, hopefully, after the acceptance of the manuscript.

This PDF file includes:

Figures S1 to S3
Supplementary text for Figures S1 to S3
Table S1
References

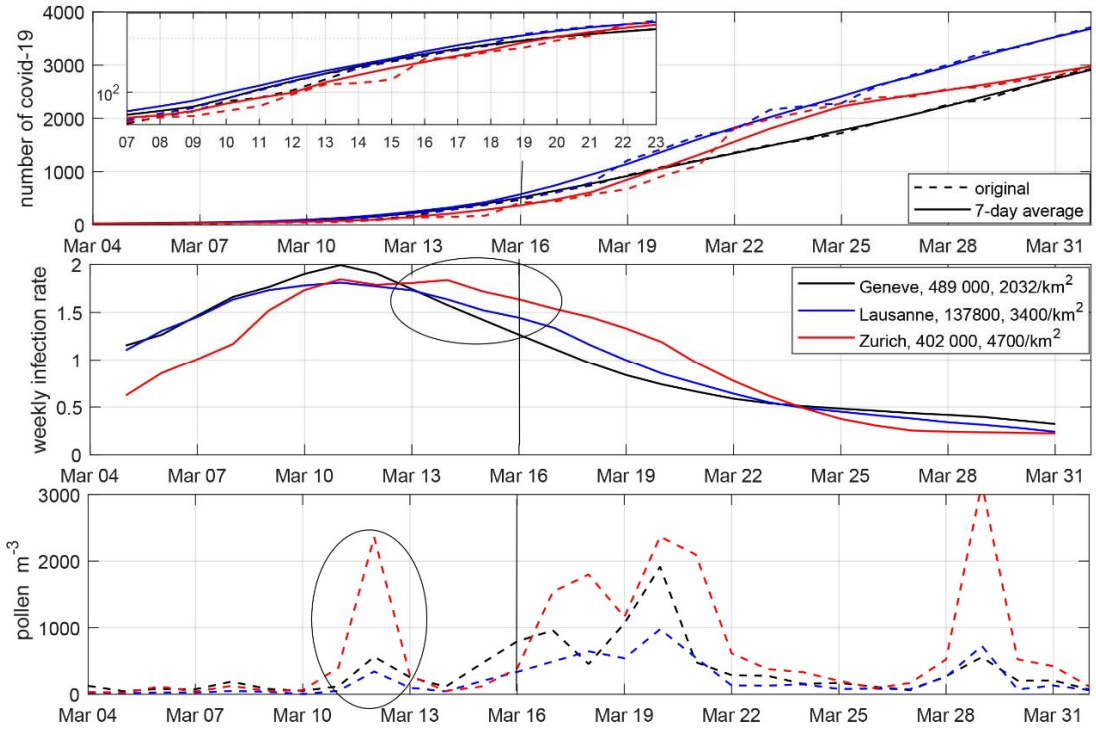

Fig. S1. Switzerland as case study to illustrate the magnitude of the pollen effect. Number of COVID-19 cases, infection rates (7-day moving average) and airborne pollen concentrations (pollen m^{-3}) are shown as a function of date for three Swiss cantons.

Supplementary Information Text for Fig. S1

The example of Switzerland illustrates the relative importance of the effects of pollen, population density and lockdown. Switzerland was one of the countries with the highest pollen concentrations for several days during the exponential phase of the pandemic, which made it possible to compare three cities in Switzerland located close to each other and having comparable climate and population densities, but different pollen concentrations.

The pollen spike on 12 March in Zurich was 5 times that of Geneva and 8 times higher than in Lausanne. As a result, the overall tendency of reduction of the infection rate from 11 March was broken in Zurich (ovals mark the spike and its effect) – and the anomaly faded out only a week later. Of note, the pollen spikes that occurred during the lockdown phase exhibited a by far less pronounced effect.

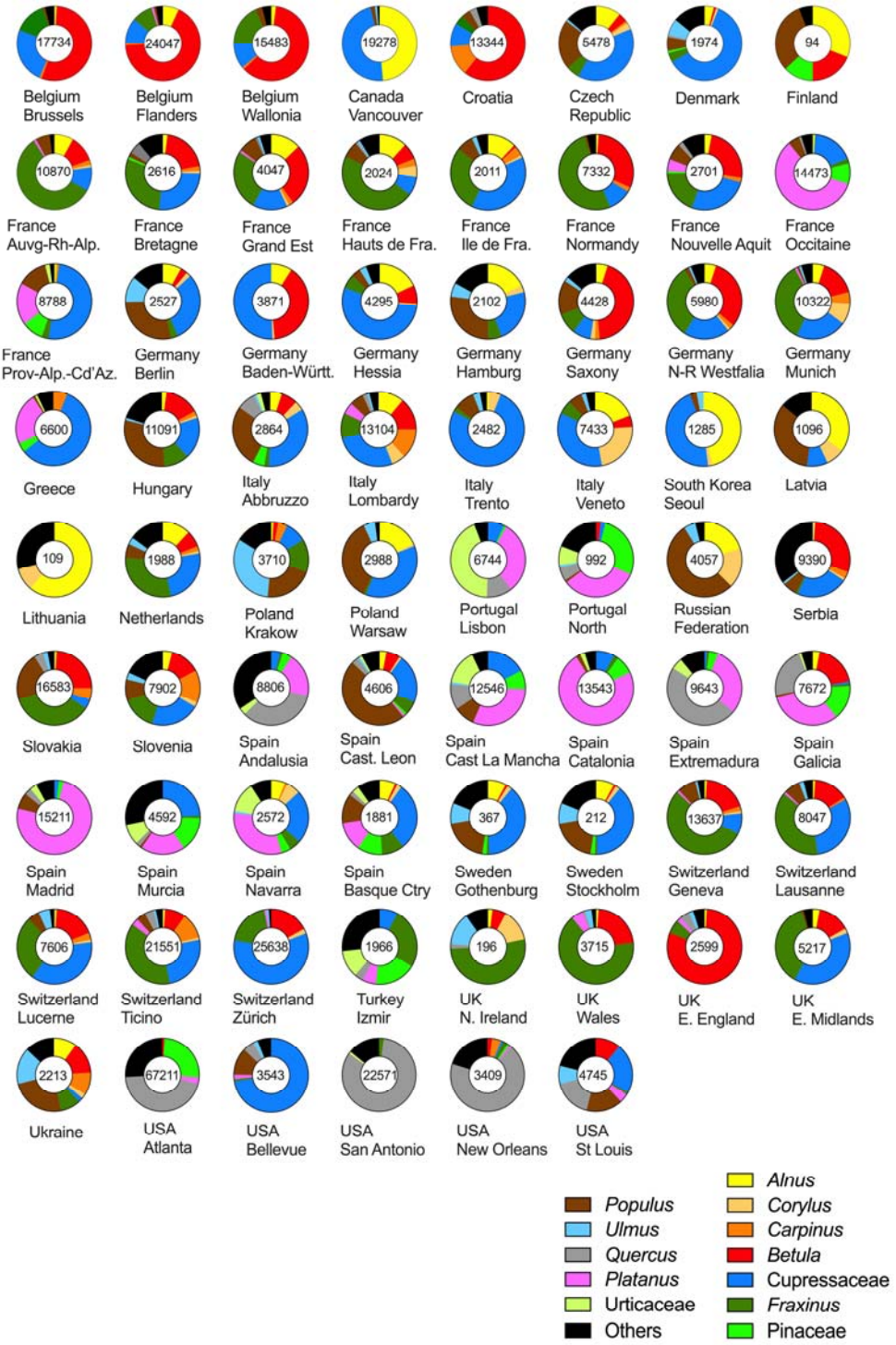

Figure S2. Donut charts of the biodiversity of all monitored airborne pollen per region, in 70 regions across the Northern Hemisphere. Focus was given on allergenic pollen primarily (color depiction), while the rest were denoted as 'Others' (black color depiction). The numbers in the middle of each chart indicate the total number of all pollen grains recorded during the study period for each region. The Southern Hemisphere has been excluded here, as the daily average pollen concentration was only 17 pollen grains per cubic meter of air, the majority belonging to grass pollen (in contrast to a daily average of more than 200 pollen in the Northern Hemisphere).

Supplementary Information Text for Fig. S2

To assess the biodiversity of the pollen time series we analysed, we show here 70 donut charts (for the Northern Hemisphere), representing the percentages of each pollen taxon as the relative contribution to the overall pollen abundance. We found that the total pollen amount actually refers to mainly allergenic pollen for the study period. The majority of the taxa included in this study refer to allergenic ones, like *Alnus*, *Betula*, *Corylus*, Cupressaceae, and *Fraxinus*. To define which pollen types are 'allergenic', we followed published results per pollen taxon, e.g. as in (1) and references therein.

The allergenic taxa are denoted with color, whereas all the rest with black. The black parts are overruled by the color ones and the black pieces in the donut charts may represent a large number of taxa, like *Acer*, Myrtaceae, *Plantago*, *Salix*, but also late spring-summer emerging pollen (not yet present in abundance by the time of the study implementation), like *Ambrosia*, *Artemisia*, Chenopodiaceae, *Olea*, *Plantago*, *Rumex*, Poaceae. Even though the biodiversity is not consistent among regions and countries, with a variable ranking order of pollen taxa, the take-home message is that the non-allergenic or the not-present-yet taxa ('Others', denoted as the black parts of the donuts) could be numerous but not abundant at all, yet.

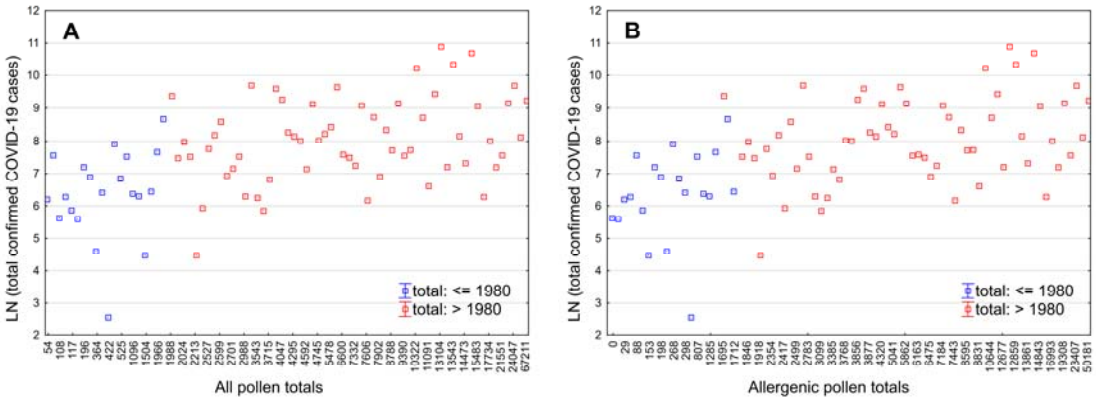

Figure S3. Scatterplot of the distribution of the total confirmed COVID-19 cases in relation to pollen totals. To analyze, in parallel, the infection cases in association with pollen abundances, we differentiated the 1st quartile of pollen data (low concentrations, as in the Southern Hemisphere), which accounted for a threshold 1980 pollen.

Supplementary Information Text for Fig. S3

To evaluate whether the total amount of pollen per region is the most representative and appropriate for our research question, we assessed the whole diversity of airborne pollen taxa for each and every site out of 248 originally acquired and for all the regions and all 31 countries included in the analysis. It is clearly demonstrated that the effect of our originally calculated totals of pollen are almost identical to the newly calculated allergenic pollen by 90.7%. Regarding a potential change in the originally calculated pollen signal in the whole analysis, if we apply a fitting line, the difference of the coefficient of determination is only of the magnitude of 0.03 (significant and positive in both scenarios). The above similarity is simply due to the fact that our study period refers almost exclusively (for the Northern Hemisphere) to airborne pollen from winter-spring trees and shrubs.

Table S1. Overview of data sources for pollen and COVID-19 cases. Data from a total of 130 single aerobiological measurement stations included in the analysis. When more than 2 sites were equally eligible, we picked the site(s) with the highest population.

Country	Köppen climate	Region of pollen data (*n*)	Region of COVID-19 data	Source of COVID-19 data
Africa, South	Csb	Cape Town (1)	West Cape	https://www.nicd.ac.za/covid-19-update-61/
Africa, South	Cfa	Durban (1)	Kwa Zulu-Natal	
Africa, South	Bsh	Kimberley (1)	North Cape	
Argentina	Cfa	Bahia Blanca (1)	Buenos Aires	https://www.argentina.gob.ar/salud/coronavirus-COVID-19
Australia	Cfa	Brisbane (1)	Queensland	https://www.health.gov.au/news/health-alerts/novel-coronavirus-2019-ncov-health-alert/coronavirus-covid-19-current-situation-and-case-numbers
Australia	Cfb	Australian Capital Territory (1)	Canberra	
Australia	Cfa	Sydney (1)	New South Wales	
Australia	Cfb	Launceston (1)	Tasmania	
Belgium	Cfb	Brussels (1)	Brussels (metropolitan area)	Sciensano: https://epistat.wiv-isp.be/covid/
Belgium	Cfb	Genk (1)	Flanders	
Belgium	Cfb	Tournai (1)	Wallonia	
Canada	Cfb	Vancouver (2)	Greater Vancouver	British Columbia COVID-19 Dashboard: https://experience.arcgis.com/experience/a6f23959a8b14bfa989e3cda29297ded
Croatia	Cfa	Zagreb (1)	Croatia	Ministarstvo zdravstva Republike Hrvatske: https://www.koronavirus.hr
Czech Republic	Dfb	Prague (1)	Czech Republic	https://onemocneni-aktualne.mzcr.cz/covid-19
Denmark	Dfb	Copenhagen (1)	Denmark	Statens Serum Institut: https://www.ssi.dk/aktuelt/sygdomsudbrud/coronavirus/covid-19-i-danmark-epidemiologisk-overvaagningsrapport
Finland	Dfb	Helsinki (1)	Finland	yle.fi: https://yle.fi/uutiset/3-11300232
France	Cfb	Auvergne-Rhone-Alpes (4)	Auvergne/Rhone/Alpes	ARS/Santé Publique France/Ministère des Solidarités/Santé: https://www.ars.sante.fr
France	Cfb	Bretagne (3)	Bretagne	
France	Cfb	Grand Est (3)	Grand Est	
France	Cfb	Hauts de France (2)	Hauts de France	
France	Cfb	Paris (1)	Ile de France	
France	Cfb	Caen (1)	Normandy	
France	Cfb	Nouvelle Aquitaine (2)	Nouvelle Aquitaine	
France	Cfb	Occitaine (2)	Occitaine	
France	Csa	Provence-Alpes-Cote d´Azur (4)	Provence-Alpes-Cote d´Azur	
Germany	Cfb	Berlin (1)	Berlin	
Germany	Cfb	Freiburg (1)	Baden-Wuerttemberg	

Germany	Cfb	Fulda (1)	Hesse	Robert Koch Institute: https://www.rki.de/DE/Home/homepage_node.html
Germany	Cfb	Hamburg-Borstel (1)	Hamburg	
Germany	Cfb	Leipzig (1)	Saxony	
Germany	Cfb	Mönchengladbach (1)	North Rhine-Westphalia	
Germany	Dfb	Bavaria (2)	Bavaria	
Greece	BSk	Thessaloniki (1)	Greece	https://covid19.gov.gr
Hungary	Dfa	Budapest (1)	Hungary	https://koronavirus.gov.hu
Italy	Cfa	L'Aquila (1)	Abruzzo	Ministero della Salute: http://www.salute.gov.it/nuovocoronavirus
Italy	Cfa	Lombardy (5)	Lombardy	
Italy	Cfa	San Michel all' Adige (1)	Autonomous Province of Trento	
Italy	Cfa	Padua (1)	Veneto	
Korea, South	Cwa	Seoul (1)	Seoul	ncov.mohw.go.kr/en
Latvia	Dfb	Riga (1)	Latvia	https://covid19.gov.lv/en/node/16457
Lithuania	Dfb	Siauliai (1)	Lithuania	https://koronastop.lrv.lt/en/
Netherlands	Cfb	Netherlands (2)	Netherlands	Rijksinstituut voor Volksgezondheid en Milieu: https://www.rivm.nl/en/novel-coronavirus-covid-19/current-information
Poland	Dfb	Krakow (1)	Lesser Poland	Serwis Rzeczypospolitej Polskiej: https://www.gov.pl/web/koronawirus/wykaz-zarazen-koronawirusem-sars-cov-2
Poland	Dfb	Warsaw (1)	Warsaw	
Portugal	Csa	Lisbon (1)	Lisbon and Tagus Valley	Direção-Geral da Saúde: https://covid19.min-saude.pt
Portugal	Csb	Porto (1)	North Portugal	
Russian Federation	Dfb	Moscow (1)	Russian Federation	https://coronavirus-monitor.ru/coronavirus-v-moskve/
Serbia	Cfa	Novi Sad (1)	Serbia	Статистика COVID-19 у Србији: https://covid19.data.gov.rs
Slovakia	Dfb	Bratislava (1)	Slovakia	Koronavírus a Slovensko: korona.gov.sk
Slovenia	Dfb	Ljubljana (1)	Slovenia	https://www.gov.si/teme/koronavirus/
Spain	Csa	Andalucia (3)	Andalucia	https://cnecovid.isciii.es/covid19/
Spain	Csa	Castilla y Leon (11)	Castilla y Leon	
Spain	Cfb	Castilla-La Mancha (6)	Castilla-La Mancha	
Spain	Csb	Catalonia (5)	Catalonia	
Spain	Csa	Extremadura (5)	Extremadura	
Spain	Csb	Galicia (3)	Galicia	
Spain	Csa	Madrid (1)	Madrid	
Spain	Bsh	Cartagena (1)	Murcia	
Spain	Bsh	Navarra (3)	Navarra	
Spain	Cfb	Basque country (3)	Basque country	
Sweden	Dfb	Gothenburg (1)	Västra Götaland	https://www.folkhalsomyndigheten.se/smittskydd-
Sweden	Dfb	Stockholm (1)	Stockholm	

				beredskap/utbrott/aktuella-utbrott/covid-19/
Switzerland	Cfb	Geneva (1)	Geneva	https://www.bag.admin.ch/bag/en/home/krankheiten/ausbrueche-epidemien-pandemien/aktuelle-ausbrueche-epidemien/novel-cov.html
Switzerland	Cfb	Lausanne (1)	Lausanne	
Switzerland	Cfb	Lucerne (1)	Lucerne	
Switzerland	Cfb	Ticino (2)	Ticino	
Switzerland	Dfb	Zürich (1)	Zürich	
Turkey	Csa	Izmir (1)	Izmir	https://covid19.tubitak.gov.tr
Ukraine	Dfb	Vinnitsya (1)	Ukraine	Department of Health and Rehabilitation of Vinnytsia Regional Council, Ukraine
United Kingdom	Cfb	Leicester (1)	East Midlands	https://www.gov.uk/guidance/coronavirus-covid-19-information-for-the-public
United Kingdom	Cfb	Ipswich (1)	East of England	
United Kingdom	Cfb	Belfast (1)	North Ireland	
United Kingdom	Cfb	Cardiff (1)	Wales	
USA	Cfa	Atlanta, Georgia (1)	Georgia	https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/cases-in-us.html
USA	Dfa	Bellevue, Nebraska (1)	Nebraska	
USA	Cfa	Lackland, San Antonio, TX (1)	San Antonio, Texas	
USA	Cfa	New Orleans, Louisiana (1)	New Orleans, Louisiana	
USA	Cfa	St. Louis, Missouri (1)	St. Louis, Missouri	

References for Supplementary Information

1. A. Damialis *et al.*, Climate Change and Pollen Allergies. In: M. Marselle, *et al.* (eds). *Biodiversity and Health in the Face of Climate Change*. Springer, Cham, pp. 47-66 (2019).