Joint Research Centre

Centre for Advanced Studies (CAS)

Kick-off Meeting 14.10.2021 (14:00-17:30) Online

Ispra, Italy

A. Abstracts

B. EPICO (brief project description)

A. Abstracts

Nikolaos Stilianakis, JRC Lead Scientist; Epidemics: Dynamics and Control project

Models in infectious disease dynamics and their role in public health

Respiratory infections, such as influenza and corona viruses can cause major epidemics and in some cases pandemics with a substantial mortality and morbidity toll. Similar observations with recurrent local epidemics account for (re)-emerging vector-borne disease outbreaks. Epidemics and pandemics can become a challenge for public health management at local, national, or international level. Quantitative tools such as mathematical modelling approaches have been used to explore the transmission dynamics and control of infectious agents. Together with statistical approaches, and modern sources of relevant data such as earth observation combined with routine surveillance data these tools can be useful for analysing and interpreting surveillance data and contribute to pandemic preparedness and response. The role of these tools in infectious disease dynamics are delineated in the case of respiratory and vector-borne diseases and how they can inform public health decisions.

Nikolaos Stilianakis is a senior scientist at the Joint Research Centre (JRC) of the European Commission and associate professor of epidemiology and biomathematics at the University of Erlangen-Nuremberg (DE). His research interests are infectious disease epidemiology with an emphasis in mathematical modelling, theoretical immunology/viral dynamics, and environmental health.

Yannis Drossinos, Senior Scientist, JRC

The role of aerosol droplets in respiratory pathogen transmission

Before the emergence and world-wide spreading of SARS-CoV-2, the medical community considered that pathogen transmission associated with respiratory droplets occurred via three mutually non-exclusive transmission modes: contact, droplet, and airborne (or aerosol) transmission. The extensive research efforts since the beginning of the Covid-19 pandemic have questioned this well-specified demarcation of respiratory-disease transmission modes. More importantly, their relative importance for SARS-Cov-2 transmission, an essential ingredient for the choice of an effective intervention strategy, has been re-evaluated. It has become apparent that biological processes (e.g., pathogen infectivity and inactivation, host immune system), behavioral patterns (e.g., inter-personal contacts, exposure duration), and physico-chemical characteristics of the expelled respiratory droplets (e.g., droplet size and number) pay a fundamental role in the transmission pathways from donor to the recipient host. I will present an epidemiological model (Susceptible-Infectious-Droplet-Recovered population compartments) to describe the transmission dynamics of a generic respiratory disease (influenza or SARS-CoV-2 data will be used in the simulations). The model incorporates these highly complex processes via a detailed description of the dynamics of a population of respiratory droplets. I will summarize the predicted dynamics of the droplets, the relative importance of the transmission modes, model predictions for the development of an epidemic, and the associated basic reproduction number. Implications for public health decisions and the importance of non-pharmaceutical interventions to curve the epidemic wave will be emphasized.

Yannis Drossinos is a Senior Research Scientist at the European Commission's Joint Research Centre. His research activities explore aspects of theoretical aerosol physics, including particle formation and transport in laminar and turbulent flows, homogeneous and heterogeneous nucleation, and statics (morphology) and dynamics (agglomeration and fragmentation) of fractal-like agglomerates. He has also studied the transmission dynamics of respiratory viruses, and more recently he has developed epidemiological models for the transmission dynamics of SARS-CoV-2. He was a Visiting Professor at the School of Mechanical and Systems Engineering, Newcastle University (2004-2010), an Honorary Research Associate of the Department of Physics and Astronomy, University College London (2014-2019), and a Visiting Researcher at the Department of Mechanical Engineering, University of Minnesota, Minneapolis (fall 2018). He currently serves as an Editor for the journal Aerosol Science and Technology.

Walter Hugentobler, EPFL, Switzerland

Missing aspects of the "Swiss Cheese Model" for epidemic control and vaccine skepticism

In the aftermath of Charles Chapin 1910 published remarkable publication "The Sources and Modes of Infection", epidemic and pandemic airborne disease control became more and more focused on transmission prevention by dilution, extraction and inactivation of the pathogen, behavioral rules and stimulation of the internal immune system by injections that bypass the human first line defence. Research efforts focused on these aspects and overlooked the powerful human first line defence against intrusion of pathogens: barrier and clearing properties of mucus and unspecific cellular defence. The fact that science and public health authorities scarcely address these aspects, although they are very present in complementary and alternative medicine, results in the gut feeling of numerous people, not being taken seriously or even being manipulated. In my experience this is an important reason for widespread vaccine skepticism.

The infographics of the "Swiss Cheese Model" for epidemic control visualize a bunch of "holy" intervention strategies and codes of behaviour. At the very end of the layered strategy appears vaccination and a seemingly defenceless, mask wearing human being. I will highlight how each of us may improve his constitutive defence and how this resilience is closely linked to disease seasonality and the two underestimated building and air conditioning related risk factors: low humidity and temperature.

Walter Hugentobler, MD. Study of Medicine at Zurich University. Postgraduate training in General Internal Medicine. GP practice (Primary Care/Family Medicine). Former lecturer at the Faculty of Medicine, Institute of Primary Care, University of Zurich. Since 2013 academic & medical advisor of Condair, Innovation and Technology AG. Since 2021 Guest member of research team LAPI (Laboratory of Atmospheric Processes and their Impacts) at EPFL. Thirty years of medical experience on "interactions of human health, indoor climate and the built environment". Publications in technical and medical journals. Partner in an interdisciplinary research team (EPFL, ETH Zurich, Virology University Hospital Zurich) investigating impacts of indoor climate conditions on Influenza and SARS-CoV-2 viruses.

Simona Bignami, Department of Demography, University of Montreal

Spatial differentials in COVID-19 infections, mortality and health care utilization in the EU: a population health approach

Even though differences in infections, hospitalisations and mortality across European countries are well-known at the aggregate level, the demographic characteristics, behaviours and outcomes of individuals affected by SARS-CoV-2 at the subnational level (regional and urban/rural) have received limited attention. We present a proposal to develop appropriate multidimensional/multistate models (as well as alternative models to validate results) to study the impact of COVID-19 on national, regional and sub-regional populations in European countries with available individual-level data through ECDC monitoring. These models will: 1) isolate the role of the age and sex structure of the population in COVID-19 mortality and health care utilization; and 2) the role of population movements in the transmission of COVID-19 and the severe outcomes associated with the disease. A comparison with Canada will allow assessing pandemic management strategies at the national and subnational levels.

Simona Bignami-Van Assche is associate professor in the Department of Demography at the Université de Montréal. She holds a Ph.D. in Demography from the University of Pennsylvania and specializes in demographic indicators of population health and social statistics. Currently she is member of the WHO/UN Technical Advisory Group on COVID-19 mortality assessment.

Vladimir Veliov, Operations Research and Control Systems, Technical University of Vienna

A new approach for modelling epidemic dynamics adapted to COVID-19

The talk will present a distributed optimal control epidemiological model that describes the dynamics of an epidemic with social distancing or vaccination as control policies. This model belongs to the class of continuous-time models, usually involving ordinary/partial differential equation, but has a novel feature. Namely, the core model is a single integral equation, which does not explicitly use transition rates between compartments. Instead, it is based on statistical information on the disease status of infected individuals, depending on the time since infection. The approach is especially relevant to COVID-19 in which infected individuals are infectious during a relatively long time before onset of symptoms.

Vladimir Veliov is full professor at the Vienna University of Technology. He is specialist in applied analysis, in particular optimization and control of dynamical systems. Author of above 110 journal publications, 40 publications in proceedings and book chapters, editor of 5 books, member of 8 editorial boards and former member of 4 more.

Ioannis Kioutsioukis, Department of Physics, University of Patras, Greece

On the predictability potential of West Nile virus risk through the MIMESIS model

In this talk we present the dynamic core of EYWA, which is a spatial forecasting model. The MIMESIS model describes the dynamics of a WNV epidemic in population health states of mosquitoes, birds and humans. The modelling framework couples epidemiological and environmental dynamical variables with surveillance data producing risk maps downscaled at a local level. We assess its hindcast skill at the municipality scale for the period 2010-2019 and present its forecast skill in operational mode during 2020. Associations between emergence of human case and climatic conditions that underline the role of seasonality in WNV transmission are discussed.

Ioannis Kioutsioukis is associate professor of atmospheric physics at the University of Patras, Greece. His primary research interest is deterministic and probabilistic predictions of complex systems in the atmosphere. Thematically, his published papers deal with weather and climate prediction (*boundary layer meteorology*, *climate change projections and impacts*) or weather dependent coupled systems (air pollution, biogenic emissions, infectious diseases, renewable energy, evapotranspiration).

Haris Kontoes, Center for Earth Observation Research and Satellite Remote Sensing, National Observatory Athens, Greece

EYWA: A key tool to the mosquito borne diseases arsenal

More than 80% of the global population lives in areas at risk of at least one major Vector-Borne Disease (VBD), with more than 700.000 deaths at a global scale. Mosquitoes are the protagonists of these vectors, carrying and transmitting various diseases to living beings and especially humans. Although specific actions and practices were adopted to control these diseases in Europe in the past decades, the re-emergence of outbreaks is just around the corner. Europe is experiencing an increasing number of human cases of Mosquito-Borne Diseases (MBD) in the last two decades, such as West Nile Virus, Malaria, Chikungunya, Dengue and Zika, both imported and indigenous, which demonstrates that Europe is not immune from MBD. The emergence of global trends such as the changing climatic and ecological conditions, global travel and trade, as well as human behavior are driving the re-emergence of these diseases, posing challenges to the national public health authorities in the European region. Thus, there is a constantly increasing need to innovate on how the continuous threats of mosquito-borne diseases are confronted, treated but most of all foreseen. This need gave birth to EYWA, a revolutionary, scalable and sustainable EarlY WArning System for Mosquito-Borne Diseases and a game changer in the domain of epidemics. It was developed under the flag of EuroGEO Action Group “Earth Observation for Epidemics of Vector-Borne Diseases-

EO4EViDence" and the coordination of BEYOND Centre of Earth Observation Research and Satellite Remote Sensing of the National Observatory of Athens. In collaboration with Ecodevelopment S.A., the Laboratory of Atmospheric Physics of the University of Patras, and 12 more interdisciplinary European organisations from Italy, France, Germany and Serbia, the EYWA team is delivering scientific excellence. EYWA supports sustainability by addressing the relevant priorities of the GEO Societal Benefit Areas, the Agenda 2030 and the Sustainable Development Goals (SDGs), such as Good Health and Well-Being (SDG 3) and Climate Action (SDG 13) and Sustainable cities and communities (SDG 11). The system is based on a plethora of satellite and in-situ Earth Observation data and state-of-the-art technological tools, leveraging scientific knowledge and ultimately proving that EO can upend our understanding in the field of epidemics. The pivotal role of EYWA is to become a key lever for Public Health authorities and decision makers, support preparedness and timely strategic design of the health system response actions, and raise citizens awareness on the expected risk, with a view to fight Mosquito-Borne Diseases.

Haris Kontoes holds the position of Research Director in the Institute for Astronomy and Astrophysics Space Applications and Remote Sensing of the National Observatory of Athens (NOA/IAASARS) and leads the Center for Earth Observation Research and Satellite Remote Sensing BEYOND (www.beyond-eocenter.eu). He received his Doctorate in Remote Sensing of the Environment (NTUA, 1992). He completed his doctoral studies holding a grant from the European Commission in the Institute for Space Applications of the Joint Research Centre at ISPRA (Environmental Mapping Group, JRC). Since 1992 he has been assuming responsibilities in managing Earth Observation operational & research projects, focusing on risk assessment and mitigation, disaster risk reduction, environmental resource management and sustainable development, agriculture and food security, energy and big data analytics for cross sector needs. He leads a multidisciplinary team of researchers with active participation in Space related projects funded by ESA, EC, COPERNICUS, GEO and International Funding Institutions (WB, EIB, etc). In his capacity as National Delegate he assumed responsibility to represent the national priorities and contributed in the formation of Space policy through his participation in Decision Making Boards and Program Committees (e.g. ESA PBEO, EC Space Program Committees (FP7, H2020), COPERNICUS Committee, Space Advisory Committee). As scientific director of BEYOND he has been coordinating the development and sustained operation of Copernicus Data Hubs (the Sentinel Greek Hub - http://beyond-eocenter.eu/index.php/web-services/sentinels-greekhub), as well as the operation of the Hellenic Sentinel Data Hub - http://sentinels.space.noa.gr) for the distribution of big Sentinel satellite data worldwide. He is assuming full responsibility for the Ground Segment facilities operated by NOA/BEYOND, thus receiving in real time a multitude of EO satellite missions. He is the coordinator of the GEO-CRADLE initiative assuming the responsibility for the uptake of Earth Observation and Copernicus in the regions of Mediterranean, N. Africa, Middle East, Balkans, and Black Sea. He is author of more than 200 publications in reviewed journals and scientific conferences. He is member of the editorial board of highly ranked Scientific Journals (IJPRS, IJRS, SENSORS, IEEE Geoscience and RS) and he is acting as member of the Advisory Boards of EU and ESA programs and initiatives. He speaks English, French and Italian.

A. EPICO: Epidemics dynamics and Control (brief project description)

The project addresses fundamental issues in prevention, preparedness, and response of epidemics. The focus is on the dynamics and control of vector-borne and respiratory infectious diseases, both posing a major global health threat. The aim is to develop a framework based on mathematical and statistical methods, and on data derived from routine and modern space surveillance systems. The project will study aspects of spatiotemporal dynamics, early warning, seasonality, the One-Health approach, transmission modes, waning immunity, pathogenesis, the immuno-epidemiology of the disease and the assessment of pharmaceutical interventions that may inform the public health decision process. The project will allow the JRC to become a source of quantitative health risk and impact assessments that should be of interest for EC DGs such, e.g., SANTE, CLIMA, ENV, ECHO, INTPA, the ECDC and the newly established Health Emergency Preparedness and Response Authority (HERA). The framework may also contribute to the global strategy of WHO and UN on global public health to achieve the health SDG 3 goal, which has also links to the climate change goal SDG 13.

JRC lead scientist of the project: Prof. Nikolaos Stilianakis (F7) (nikolaos.stilianakis@ec.europa.eu)

Staff: Dr. Augusto Fasano, Nicola Roccetti DVM, Dr. Jamie Gomez-Ramirez. External Experts: Prof. Simona Bignami-Van Assche, University of Montreal; Prof. Ioannis Kioutsioukis, University of Patras, Prof. Vladimir Veliov, Technical University Vienna. Other external and JRC collaborators: Dr. Daniela Ghio (JRC), Dr. Yannis Drossinos (JRC), Dr. Haris Kontoes, Greek Observatory Athens (Earth Observation data, Copernicus EU programme), and some more to join soon.

Recent selected publications of the research group directly related to the project objectives.

Kioutsioukis, I., Stilianakis, N. I., Assessment of West Nile Virus transmission risk from a weather-dependent epidemiological model and a global sensitivity analysis framework, *Acta Tropica*, 193: 129-141, 2019, doi: 10.1016/j.actatropica.2019.03.003

Parselia, E., Kontoes, Ch., Tsouni, A., Hadjichristodoulou, Ch., Kioutsioukis, I., Magiorkinis, G., Stilianakis, N. I., Satellite earth observation data in epidemiological modelling of malaria, dengue, and West Nile virus: A scoping review, *Remote Sensing,* 11:1862-1901, 2019, doi:10.3390/rs11161862

Drossinos, Y., Stilianakis, N. I., What aerosol physics tells us about airborne pathogen transmission, *Aerosol Science and Technology*, 54: 639-643, 2020, doi.org/10.1080/02786826. 2020.1751055

Weber, T. P., Stilianakis, N. I., Fomites, hand, and the transmission of respiratory viruses, *Journal of Occupational and Environmental Hygiene*, 18:1-3, 2021, doi:10.1080/15459624.2020.1845343

Kioutsioukis, I., Stilianakis, N.I., On the transmission dynamics of SARS-CoV-2 in a temperate climate, *International Journal of Environmental Research and Public Health*, 18(4):1660, 2021, doi.org/10.3390/ijerph18041660

Drossinos, Y., Weber, T. P., Stilianakis, N. I. Droplets and aerosols: An artificial dichotomy in respiratory pathogen transmission, *Health Science Reports*, 4:e275, 2021 (doi: 10.1002/hsr2.275)

Bignami-Van Assche, S., Boujija, Y., Ghio, D., Stilianakis, N .I. Beware of regional heterogeneity when assessing the role of schools in the SARS-CoV-2 second wave in Italy, *The Lancet Regional Health – Europe*, 7: 100174, 2021, doi.org/10.1016/j.lanepe.2021.100174

Angelou, A., Kioutsioukis, I., Stilianakis N.I., A climate-dependent spatial epidemiological model for the transmission risk of West Nile virus at local scale, *One Health*, 13:100330; 2021, doi.org/10.1016/j.onehlt.2021.100330

Ghio, D., Acosta, E., Fisman, D., Noymer, A., Stilianakis, N.I., Bignami-Van Assche, S.: Population health and COVID-19 in Canada: A demographic comparative perspective, *Canadian Studies in Population*, 2021, in press

Kovacevic, R., Stilianakis, N.I., Veliov, V.M., A Distributed Optimal Control Epidemiological Model Applied to COVID-19 Pandemic, *SIAM Journal on Control and Optimization*, 2021, in press