The ICM UW epidemiological model

Predicting the course of the COVID-19 epidemic in Poland.

Is it possible?

dr inż. Franciszek Rakowski

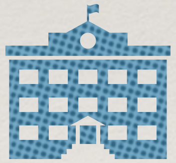
Outline of the talk

- The history of the ICM epidemic model and results for influenza spread
- Seeing a big picture: the landscape of the mathematical models for epidemic outbreaks.
- What might be the goal of the epidemic models?
- Possible analysis
  - How to choose proper level of representation
- The largest challange for detailed epidemiological model: the data.

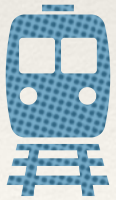
ICM UW epidemiological model

- Agent-based model (mikro-simulation model)
- Idea of the model: detailed representation of the demographic and sociological structure of Poland combined with the probabilities of virus transmission.

- Geo-localisation of each agent (a person)
  An agent is assigned (permanently or temporally) to a context.

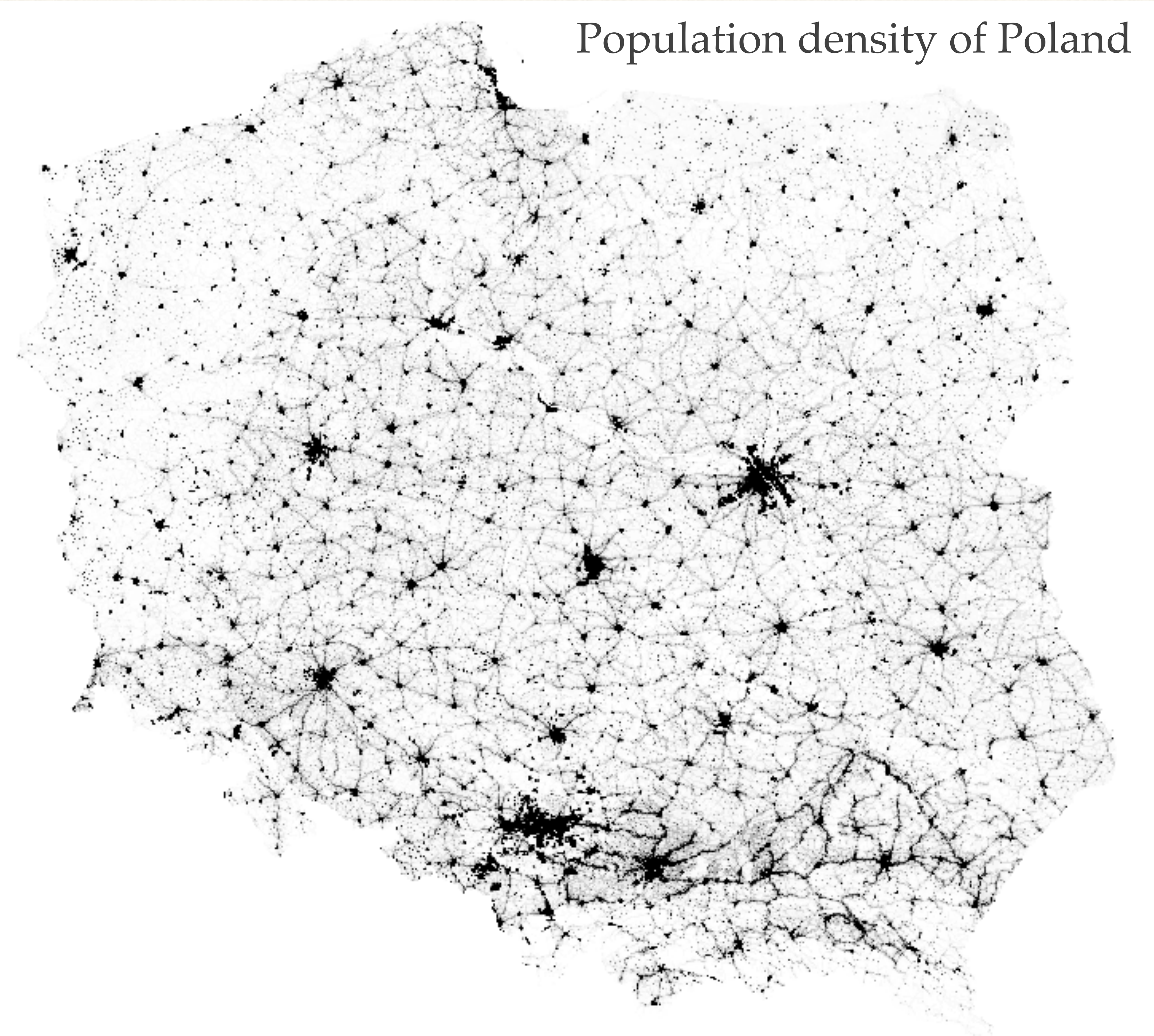


- Contexts: representations of possible contact spots: kindergartens, households, schools, workplaces, etc…

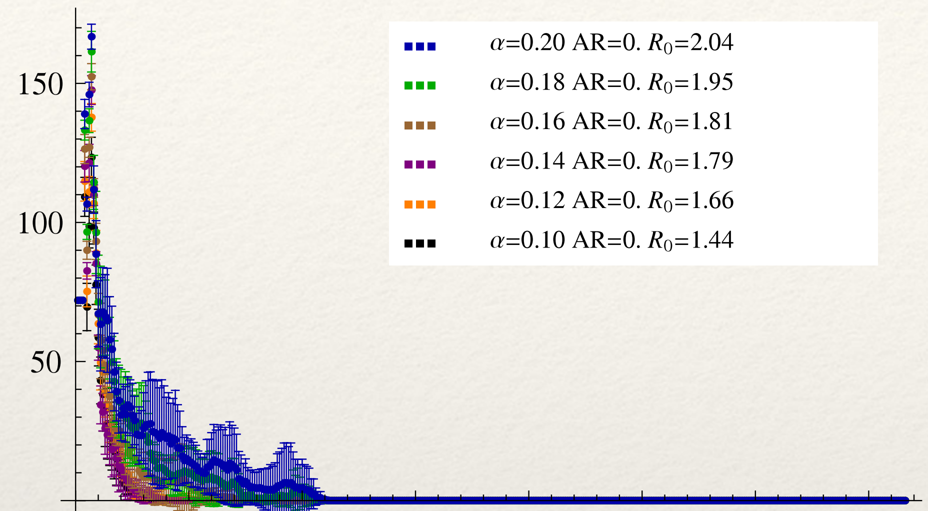


- Transportation module
  trains, cars, daily commutation

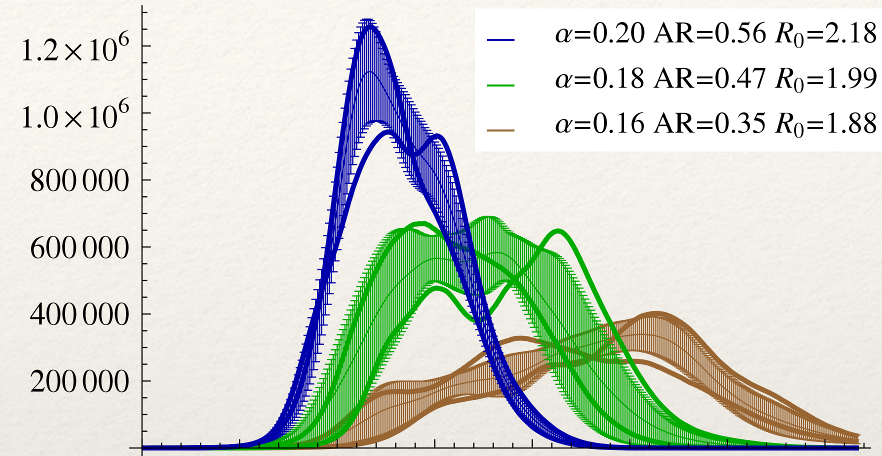
A basic layer of the model - one kilometre geo-referential grid.



Insights learned from influenza epidemic simulations.



(a) Number of ill individuals per day for $f = 0.2$.



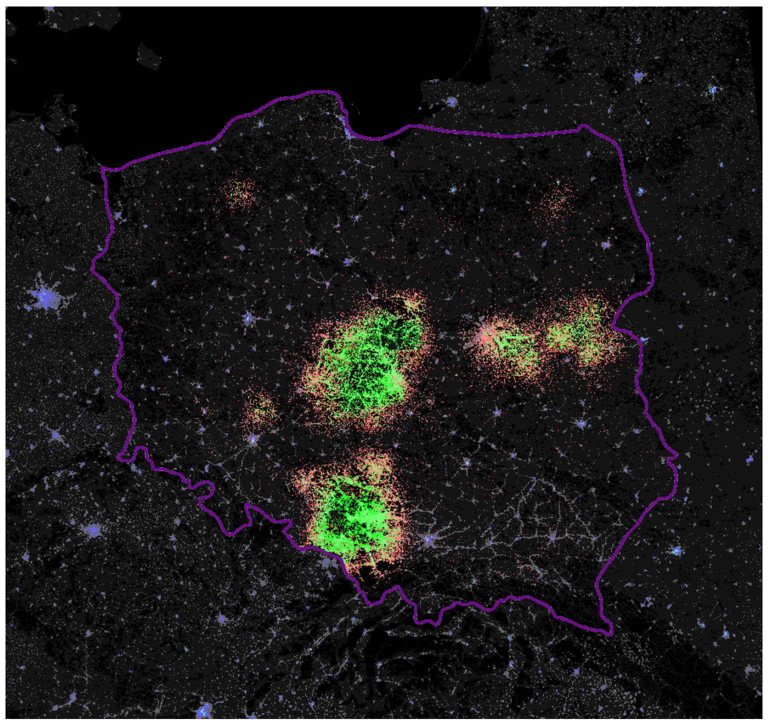
(b) Number of ill individuals per day for $f = 0.4$.

- **Often we observe two stages of epidemic: 1st: large cities (agglomerations), 2nd: small cites and villages (often seen as a second peak).**
- **One of the most important parameter is a coefficient f: fraction of infectious people staying at home (self-isolation).**
- **The structure of population density plays important role in the course of the epidemic.**
- **The work has been published in Y2010, (Physica A, JASSS)**
- **There is a movie: https://www.youtube.com/watch?v=j46osLueJKc&t=14s**

A big picture: the landscape of the epidemic models.

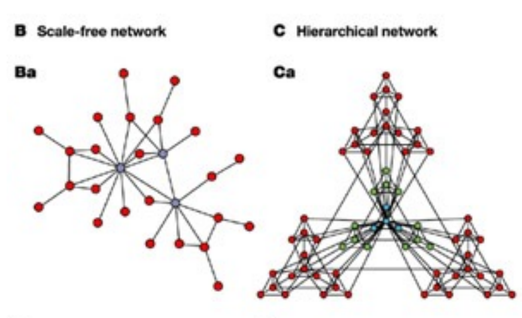
Agent-based models

1. Geo-referential models

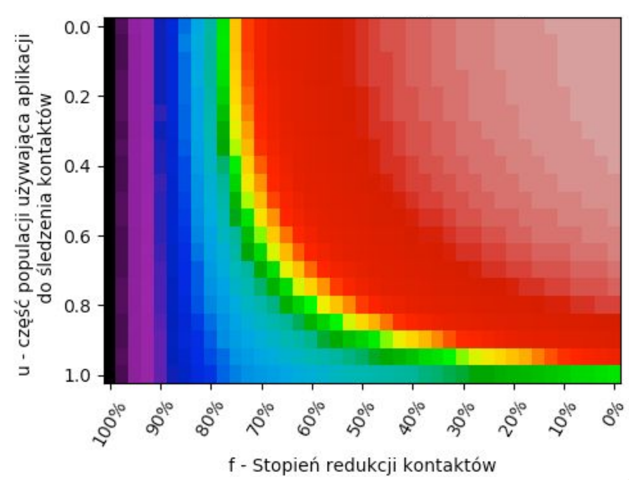


ICM model

2. Network-based models

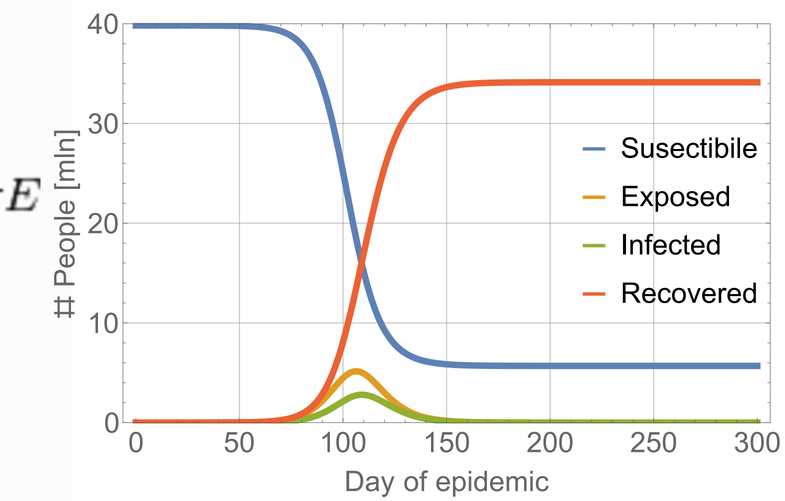


MOKOS model

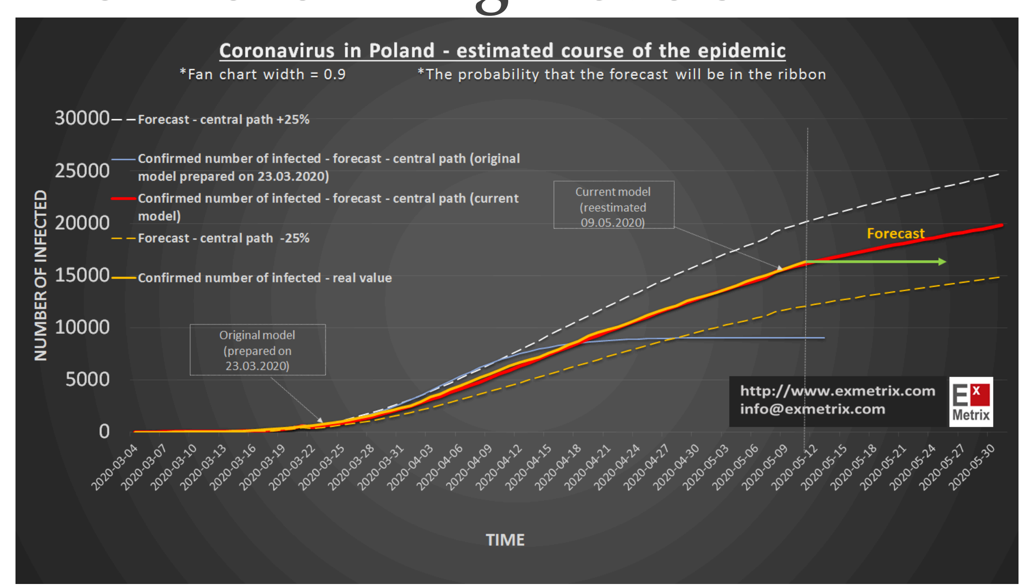


ODE's SEIR models

$$\frac{dS}{dt} = -\frac{\beta S I}{N}$$
$$\frac{dE}{dt} = \frac{\beta S I}{N} - \sigma E$$
$$\frac{dI}{dt} = \sigma E - \gamma I$$
$$\frac{dR}{dt} = \gamma I$$

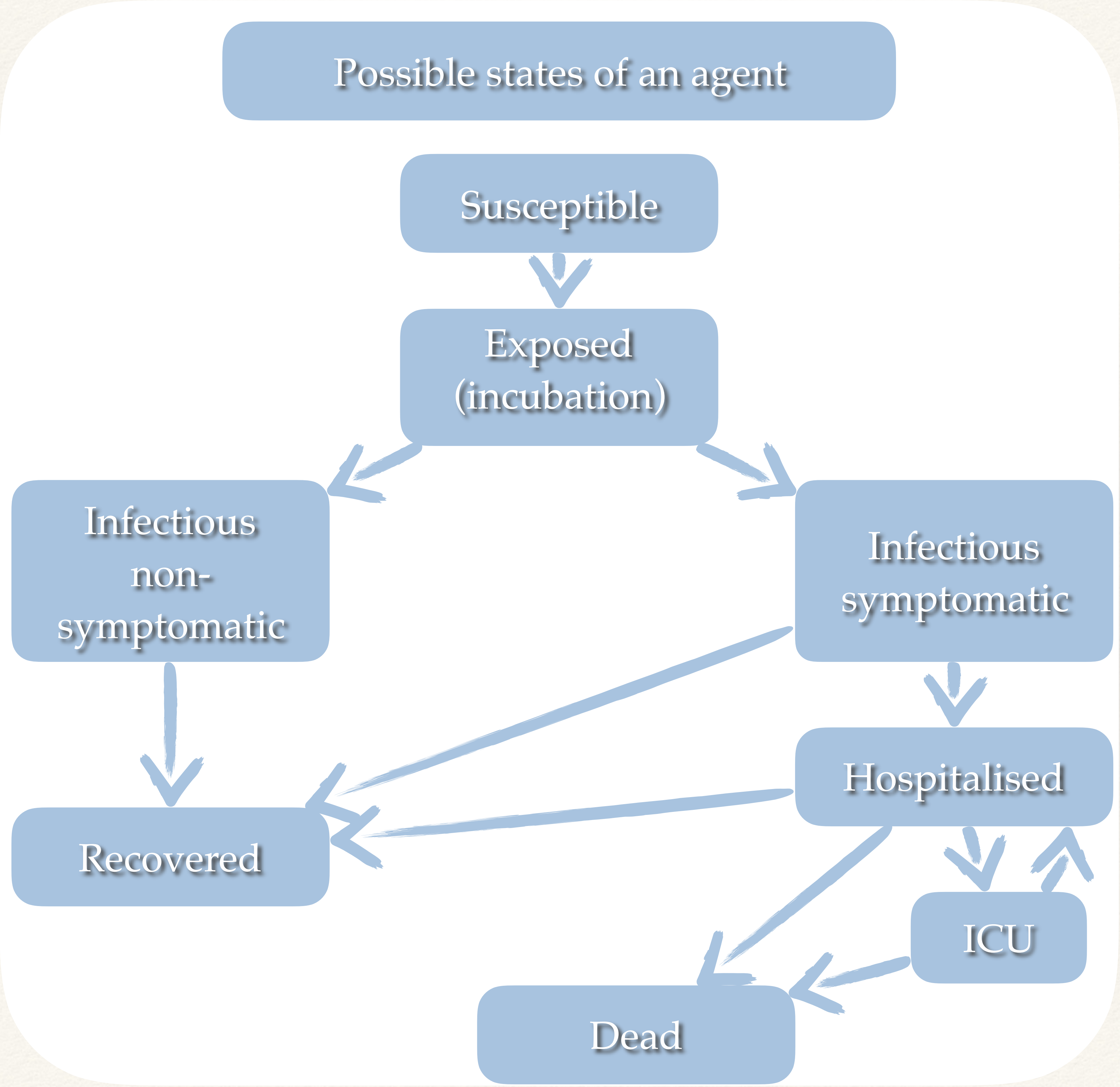


Machine learning models



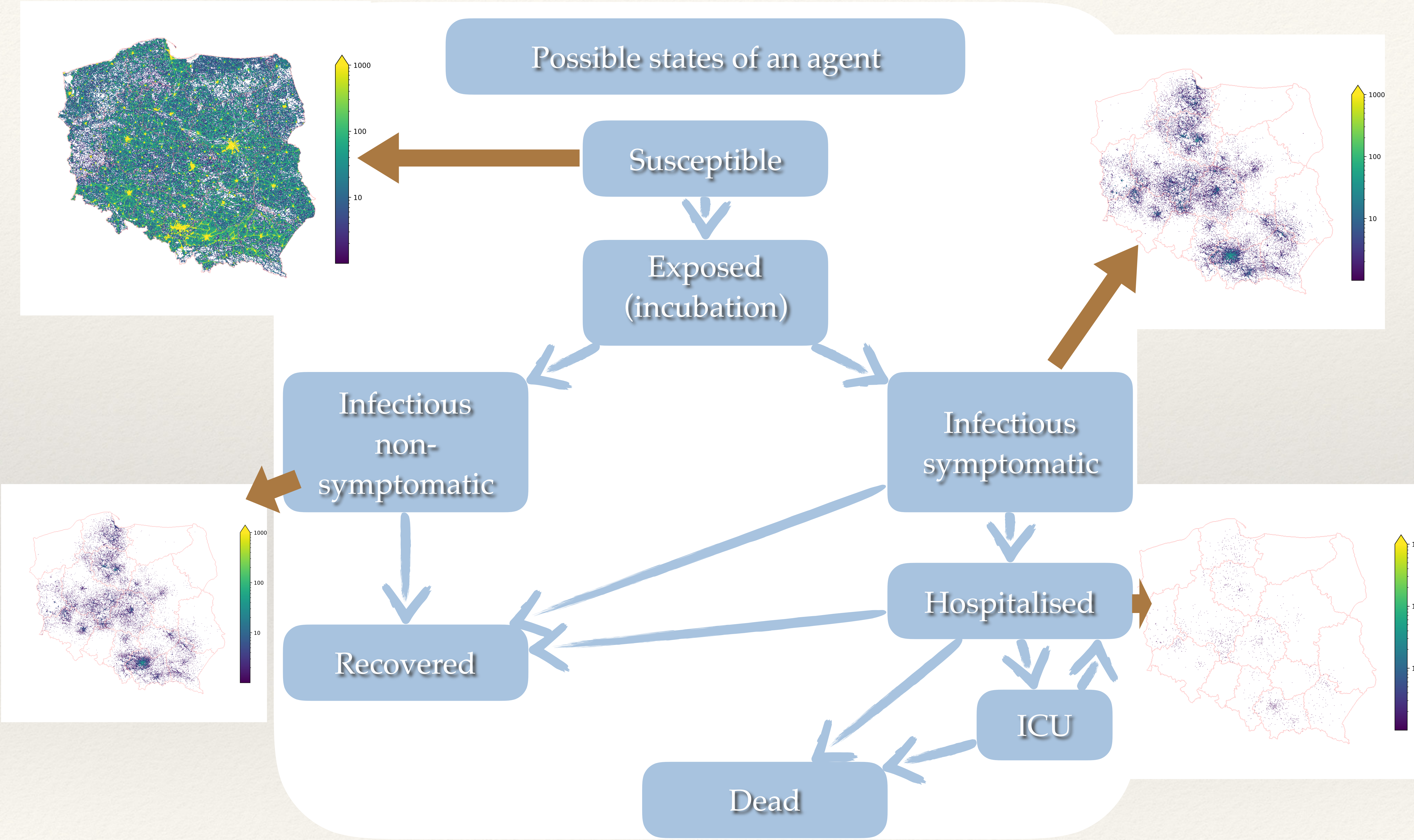
ExMetrix model

Agent-based model is also an (extended) SEIR model



- The times of being in a given state can be approximated by means or given as distributions (e.g. gamma distr.)
- The probabilities of the transmission among states are given in a form of transmission matrix

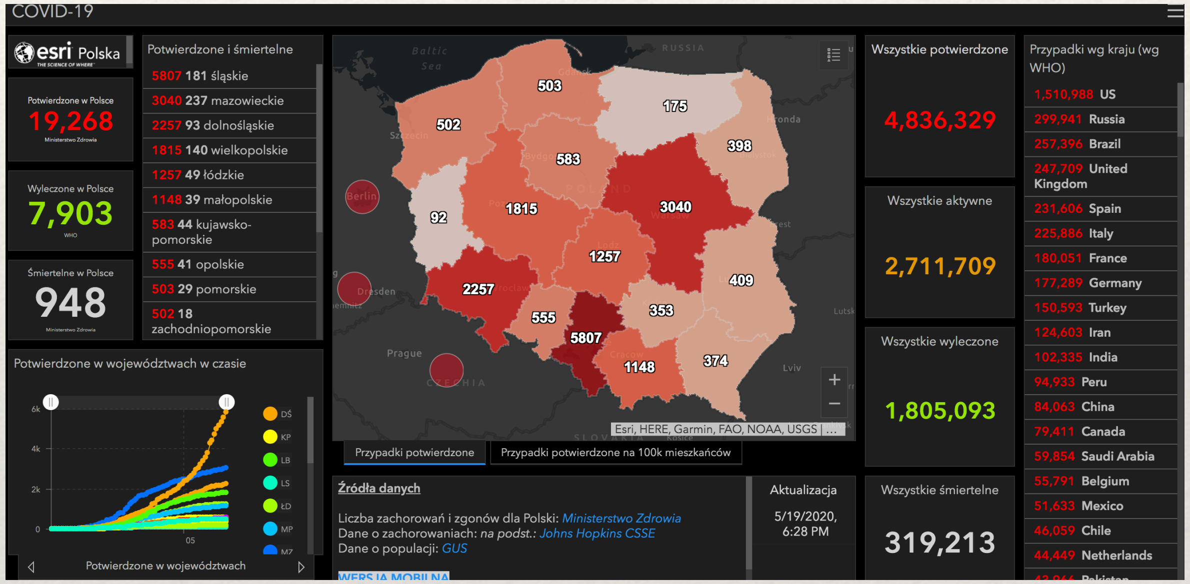
Geo-referential visualisation of the agent states.



How our model is being utilised during the time of COVID-19 pandemic?

- The ICM model is integrated with Governmental GIS system as a prognostic module.
- Reports are sent to Ministry of Health and Chancellery of Prime Minister
- Methods, results and problems will be published in scientific articles

GisCOVID-19 system
Government Centre for Security



What might be the role of epidemic model?

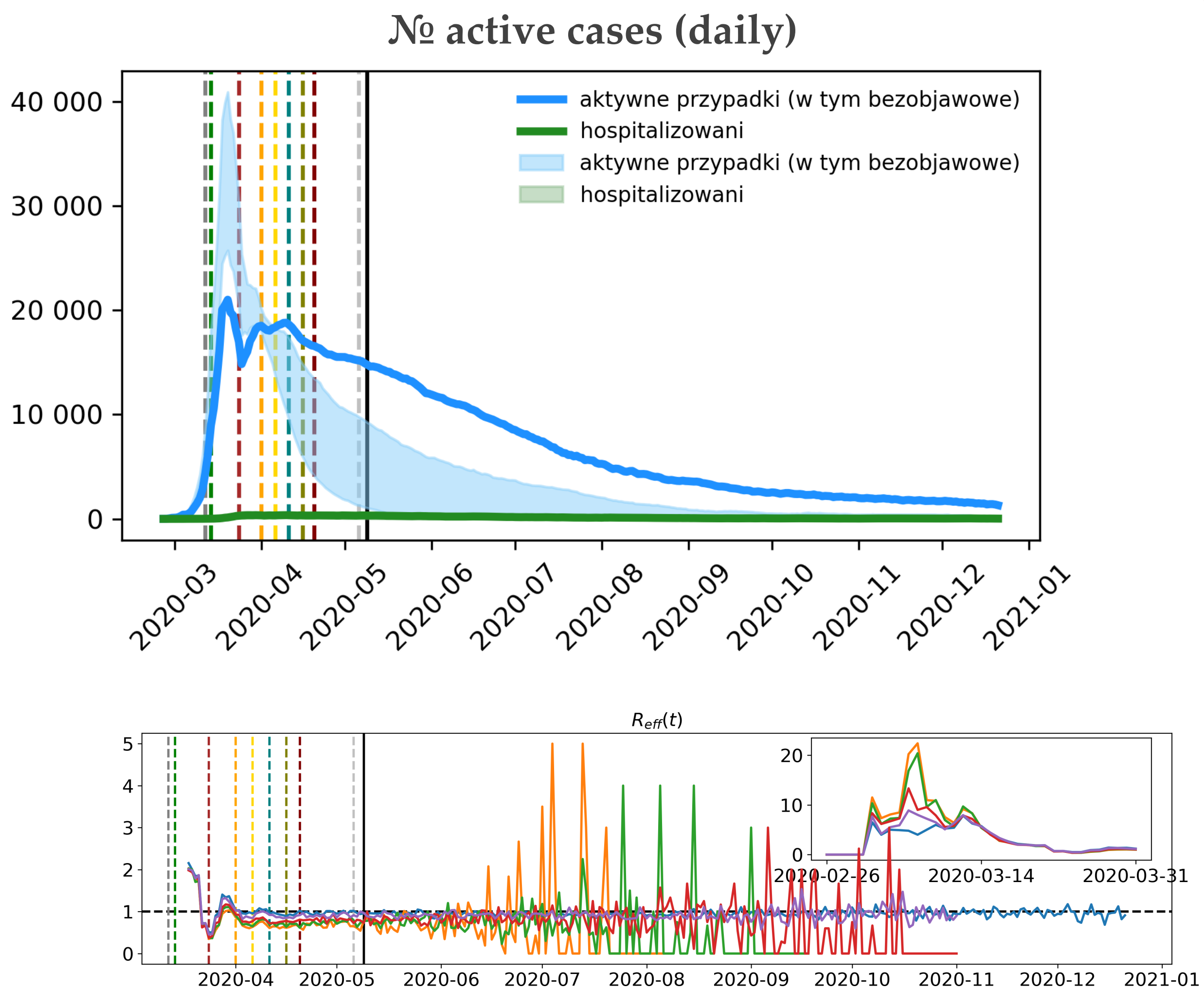
- The most prevalent questions asked by decision-makers and public opinion usually are:
  How long will the epidemic last?
  When will be the peak of the epidemic?
  How large the peak is going to be?

- Although, the models provide the answers to above given questions, the answers are strongly conditional, dependent on a measures applied and social behaviour in a future.
  Therefore, the most important role of the models, is to provide the insights to the mechanisms of epidemic spread and effective ways of mitigating it.

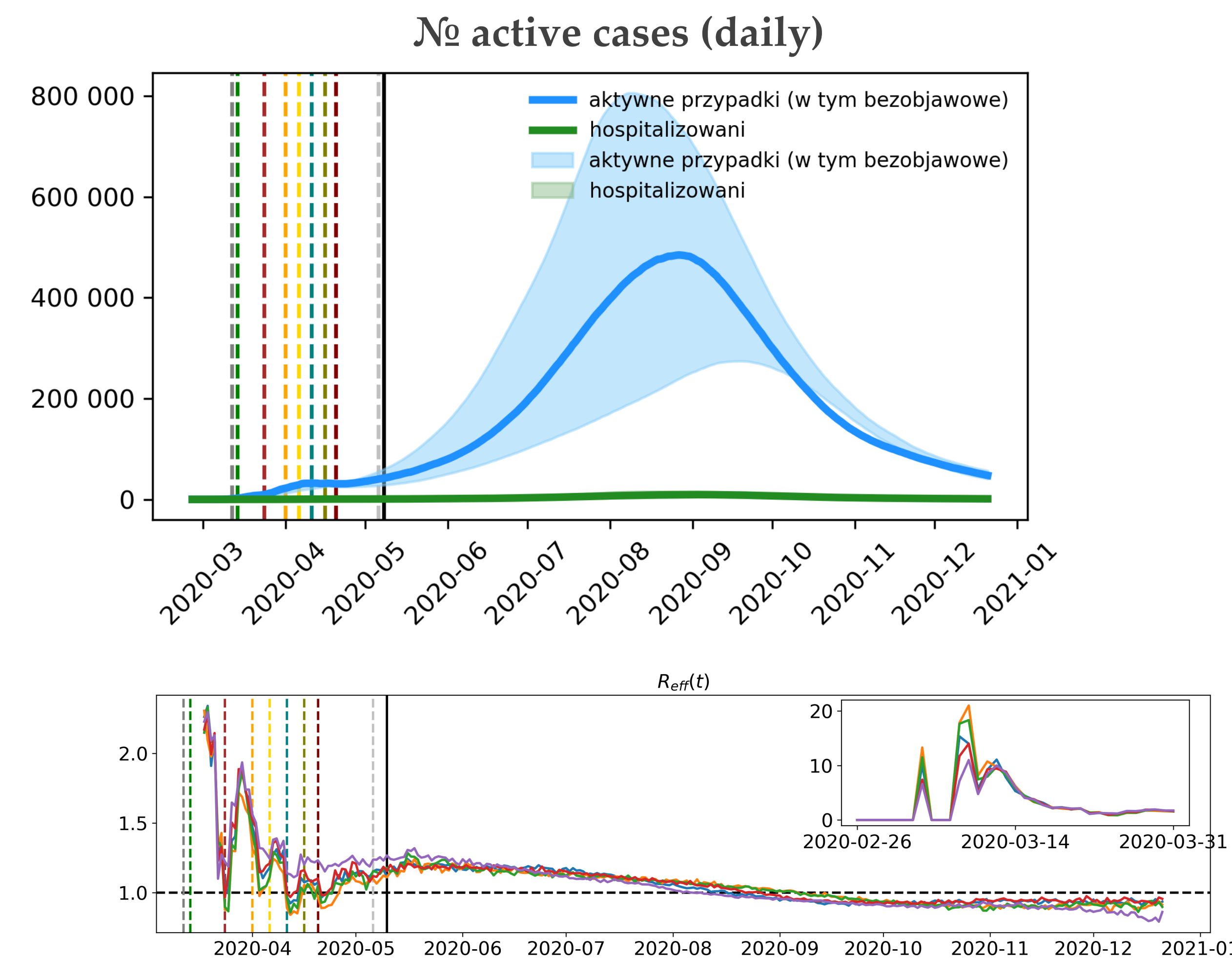
COVID-19 standard predictions

- We provide the predictions of the whole epidemic course in always, at least, in two variants:

Subcritical regime

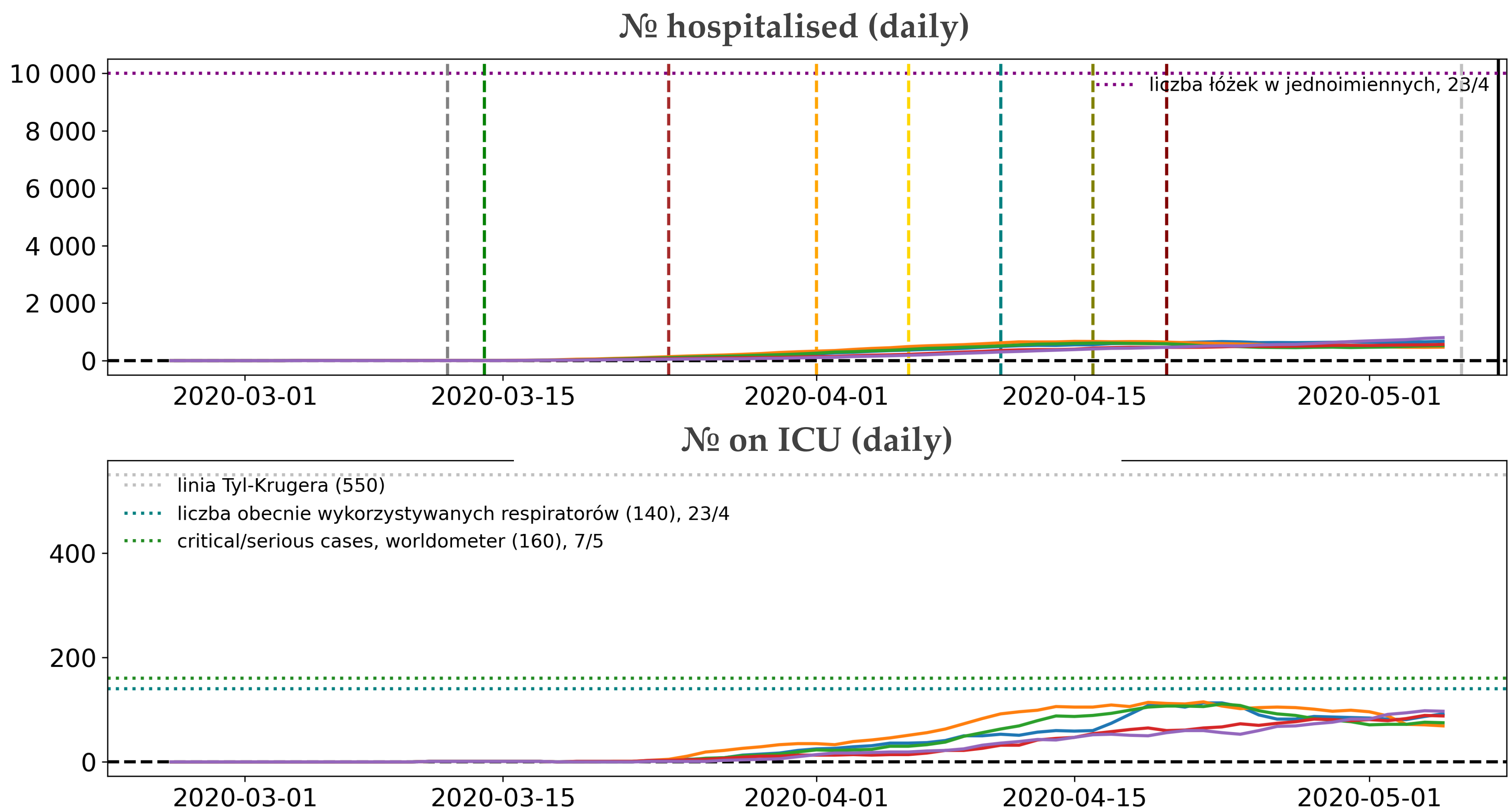


Supercritical regime



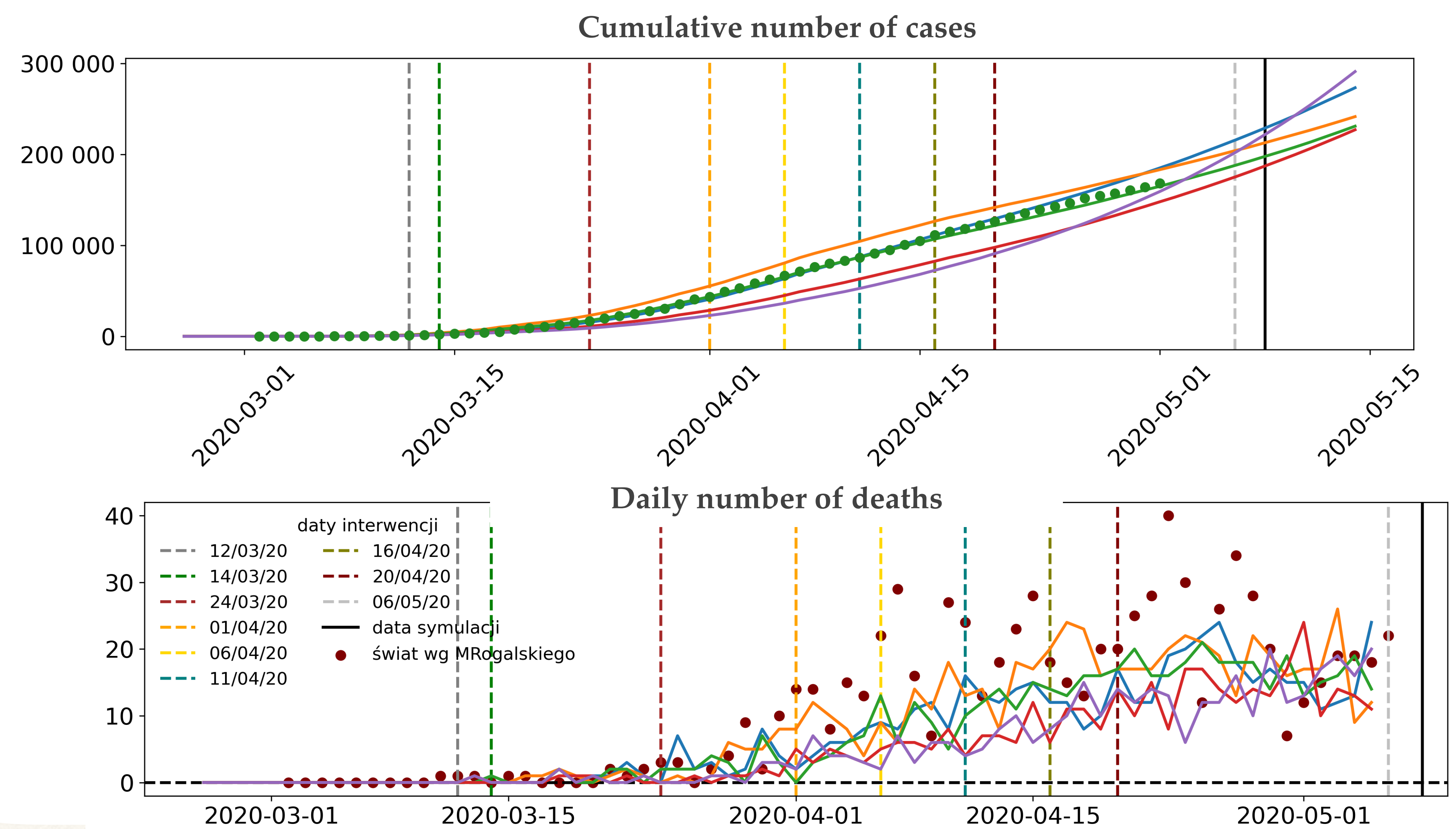
COVID-19 standard predictions

- We show possible burden of disease for each scenario:



Fitting procedure

- And the quality of the fit (to cumulative number of cases and daily deaths)



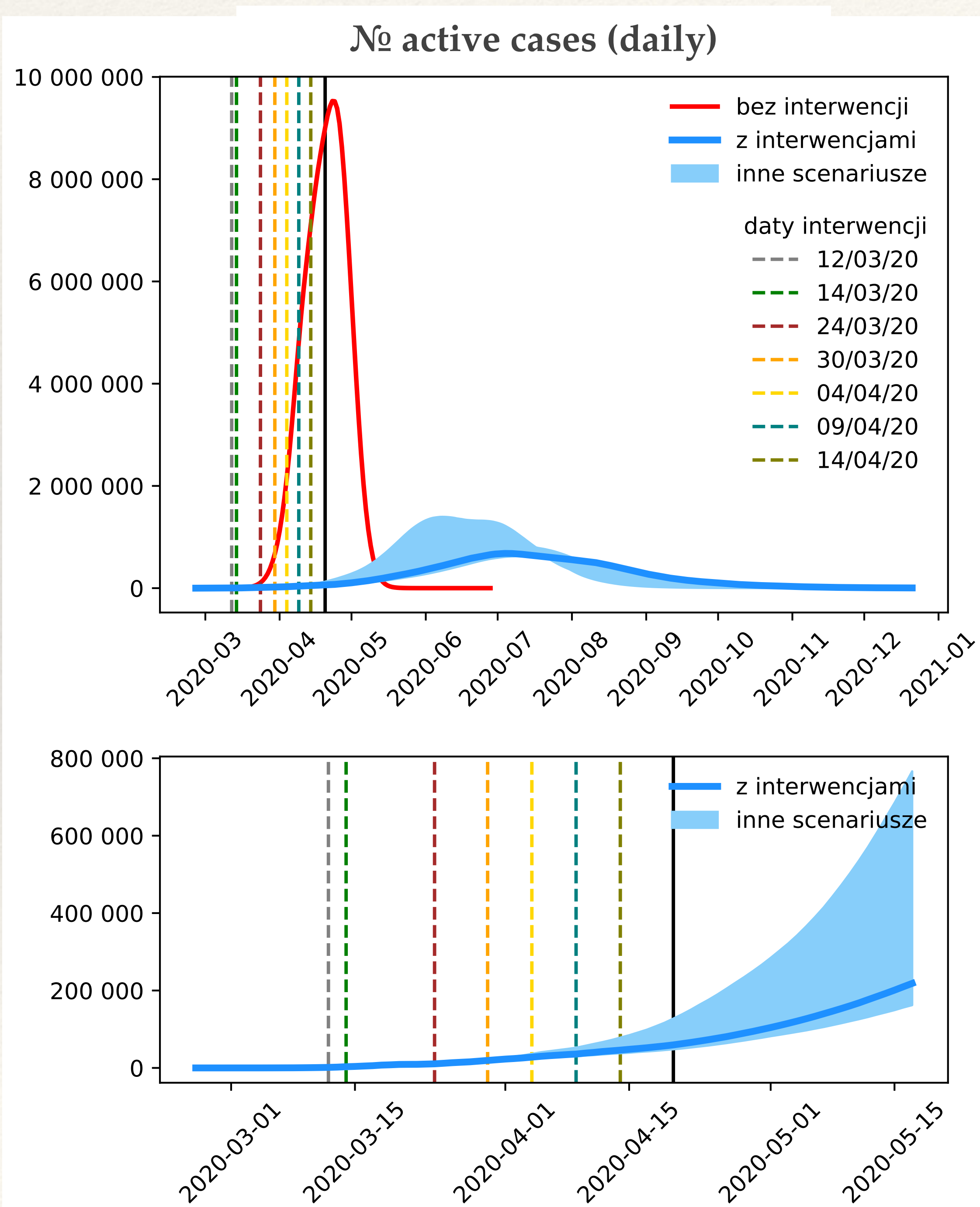
The effective mitigation strategies.

- The contact network is composed of several context layers:
  - Households
  - Educational Units
  - WorkPlaces
  - Transportation Means
  - Daily street contacts
  - Other…

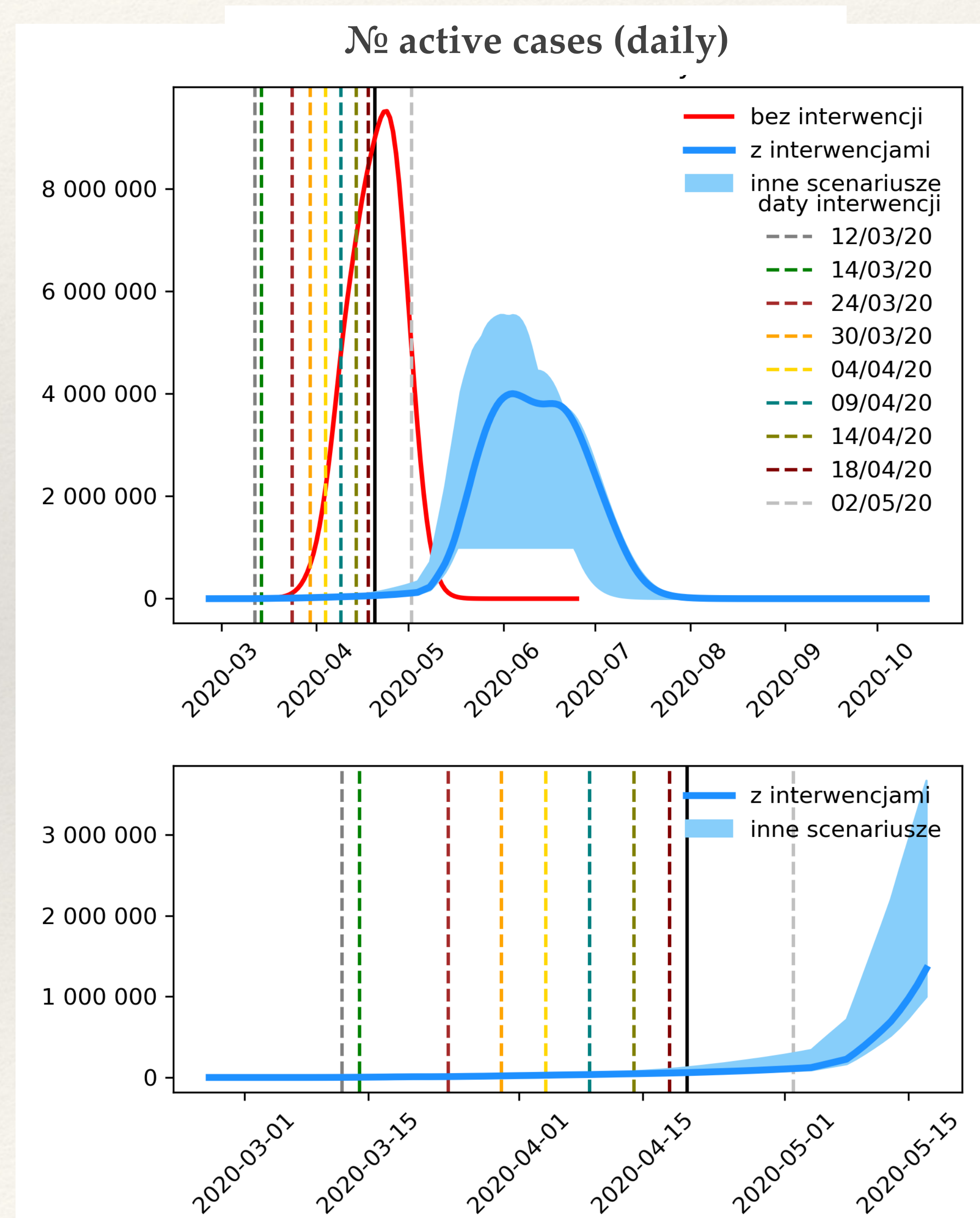
- The model allows for studying the effect of selective turning on and off given layers of contacts for a given time periods.

The effectiveness of applied measures and consequences of release (assuming we are in super-critical regime)

While keeping all the schools closed



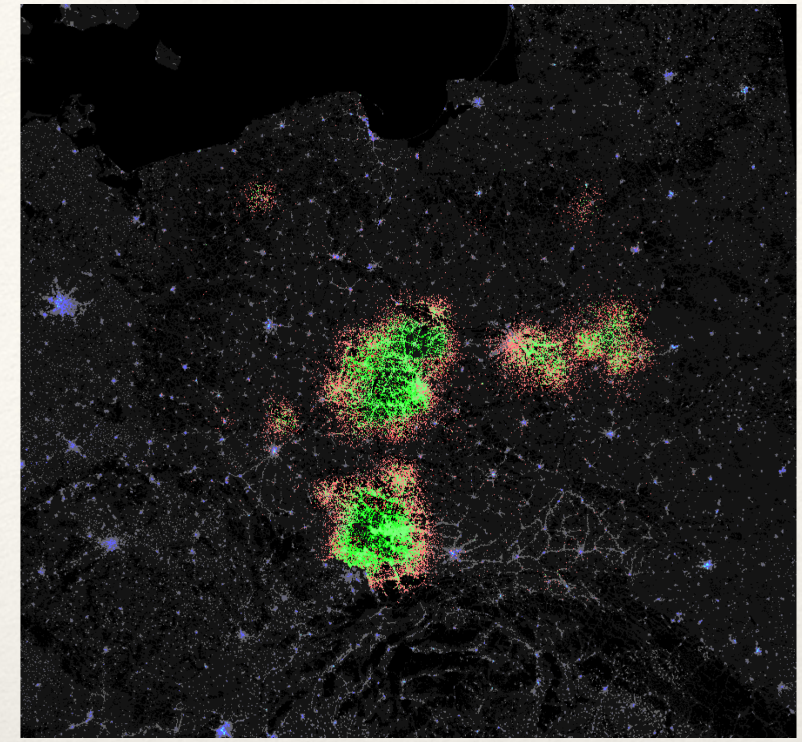
The putative consequences of school opening.



Reminder: ICM epidemic model is geo-referential

4 IV

21 IV



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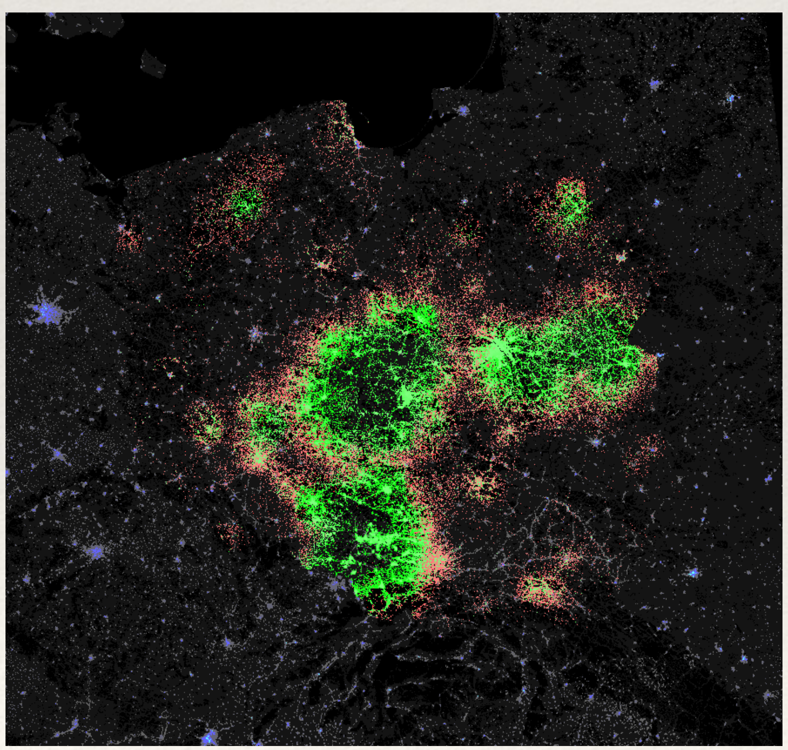
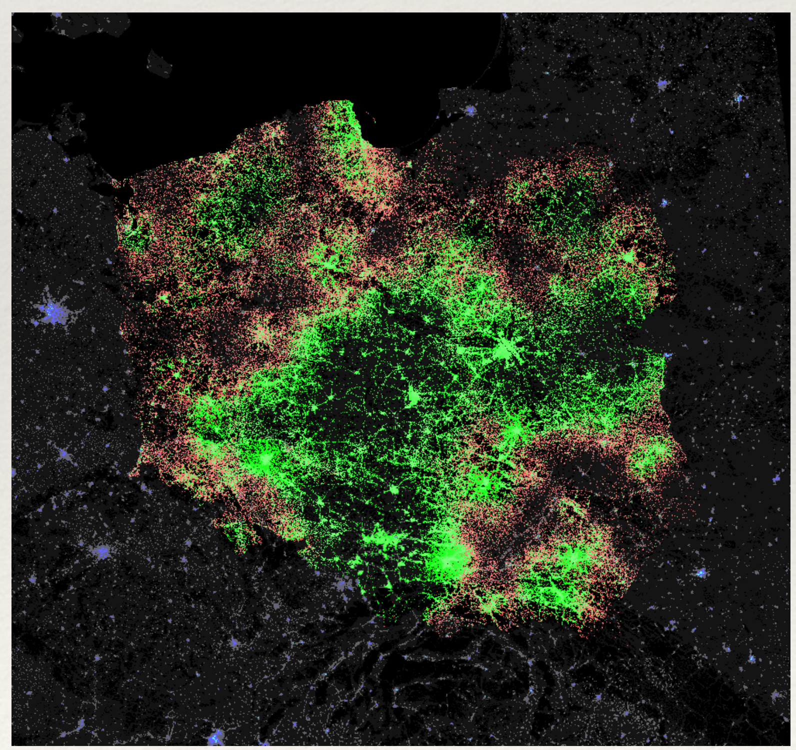


31 V



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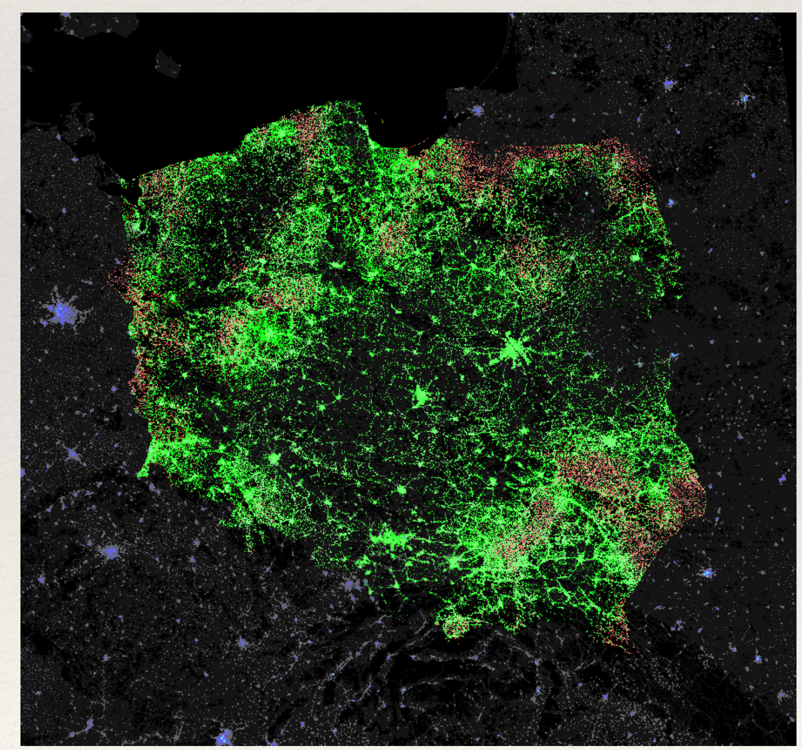

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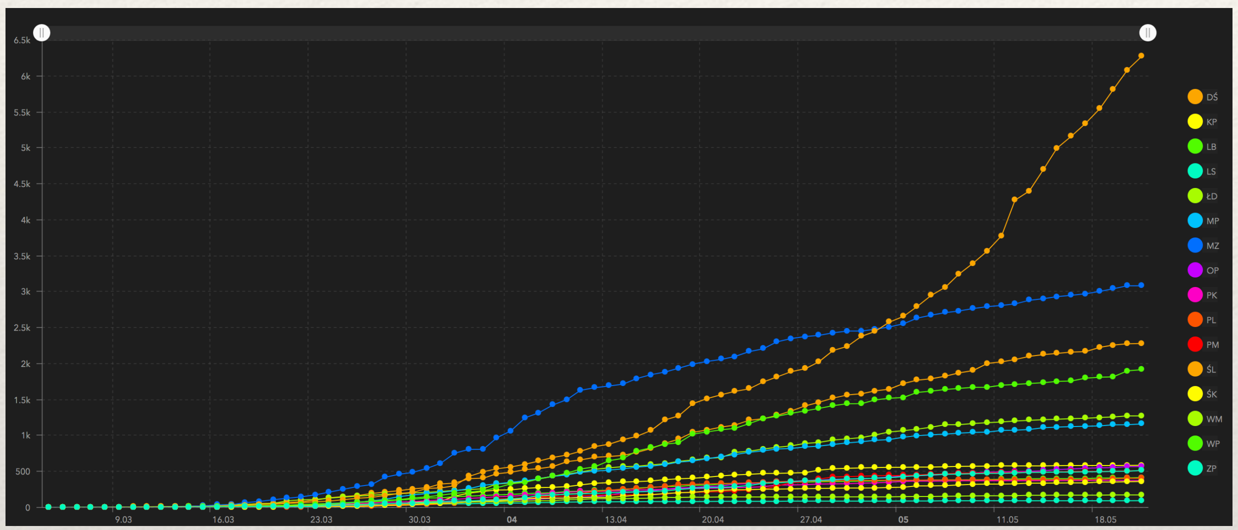
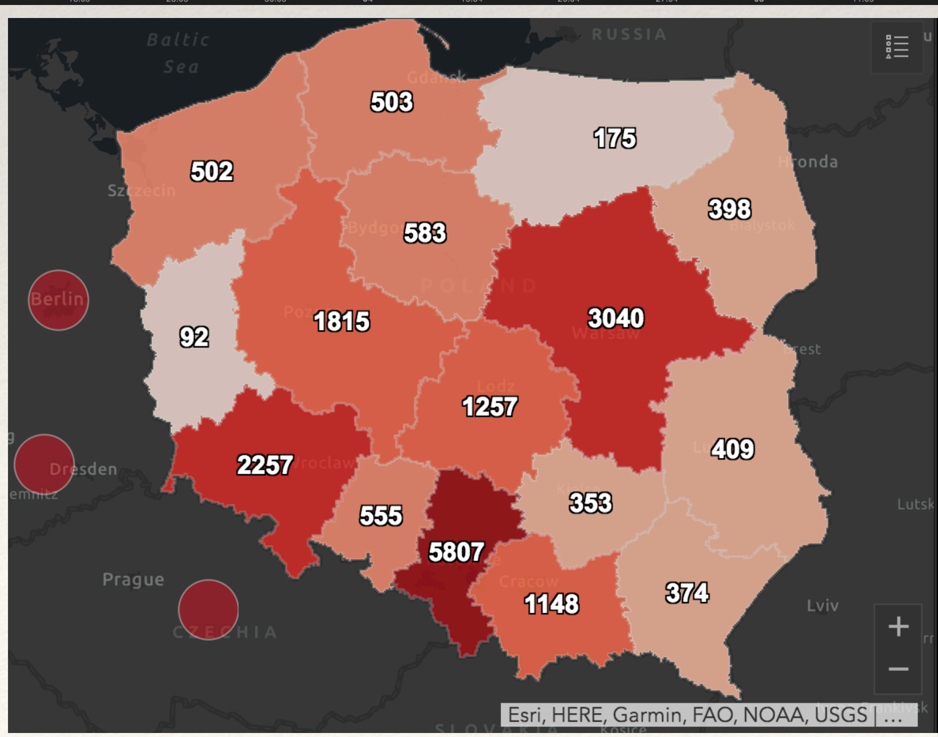
The effect of regional lockdown's.

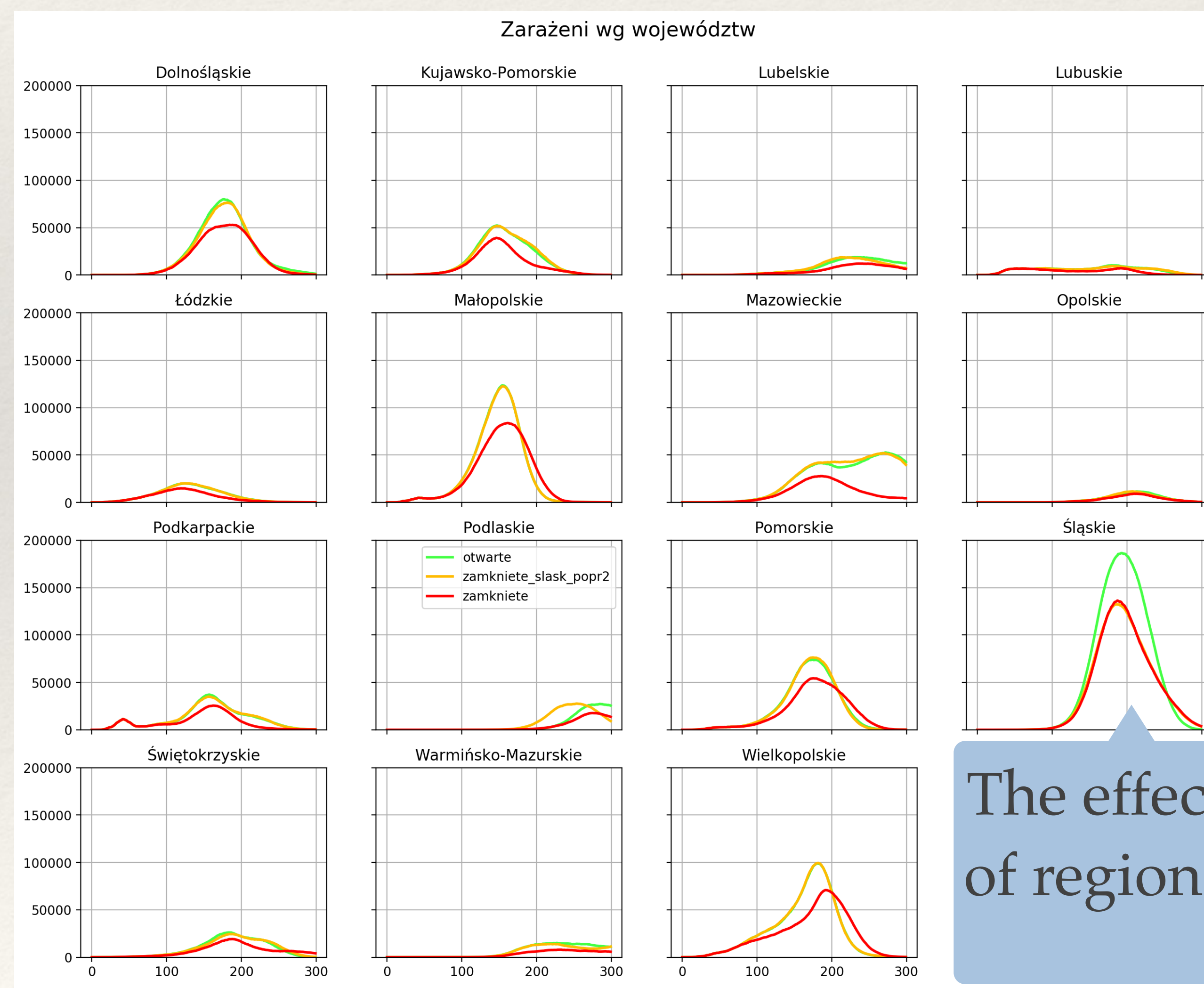
- We observe large increase of infections in Silesian voivodeship.

Actual data:





The outcome of the model, broke down into regions - the kindergarten lockdown is kept locally.



The effect of regional

The greatest challange: the data.

1. Course of the sickness

- lengths of the periods of: incubation, infectiousness
- proportion of the symptomatic to non-symptomatic subjects
- infectivity in both states: symptomatic and non-symptomatic

2. Epidemics data

- daily new cases broke down into regions
- number of quarantined and isolated people
- sources (contexts) of infection
- applied measures
- estimation of real number of positives (sero-prevalence tests)

3. Contact structure and infectivity weights

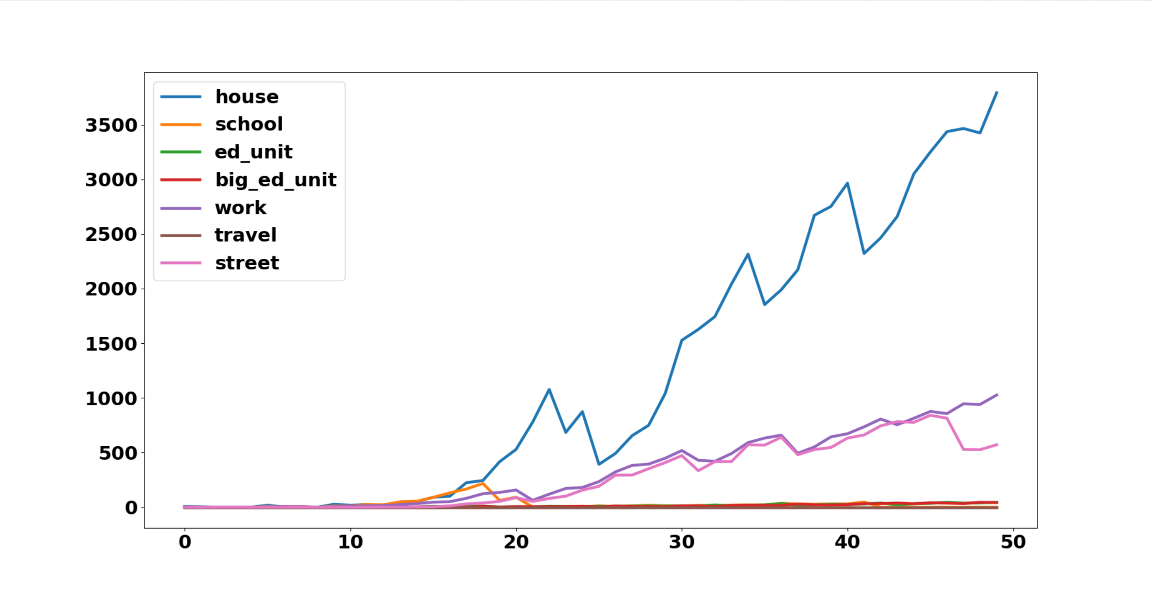
- base socio-demographical structure
- changes in contact rate along the course of epidemic in contexts
- proportion of infectivity in various contexts
- travel reduction

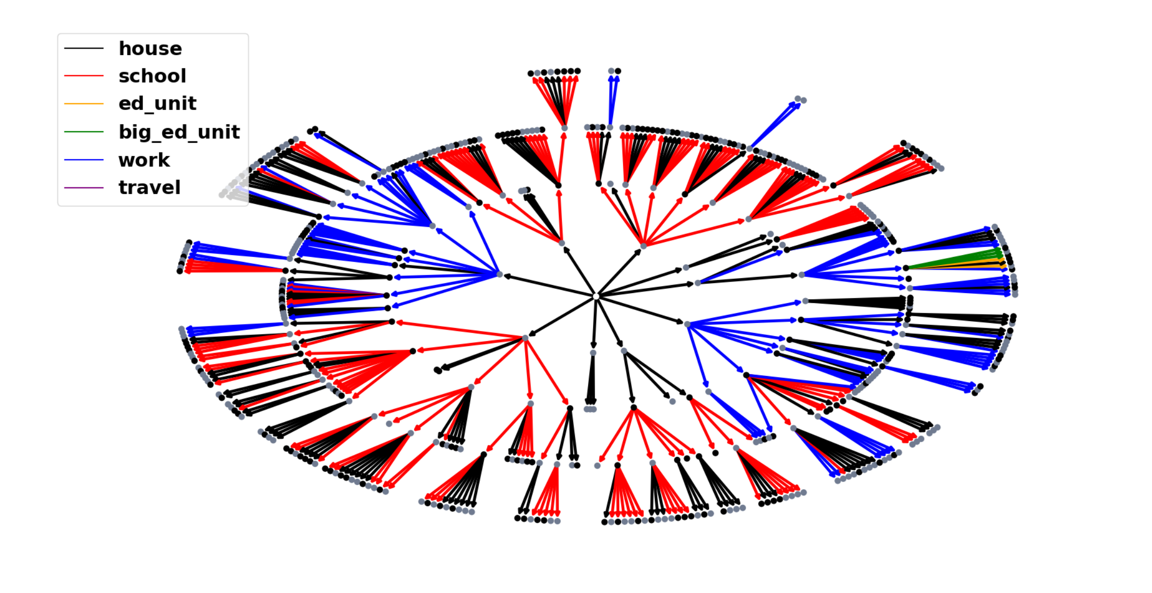
Possible ways of calibration of contact structure and weights

Useful data sets:

- Ministry of Health report about putative infection sources (contexts).
- Large poll, carried out for assessment of the intensity of contacts in various contexts

Model outcome,
to be fitted to the actual datasets.





The ICM team:

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- Karol Niedzielewski, dr Łukasz Górski, dr Magdalena Gruziel-Słomka, dr Rafał Bartczuk, dr Jędrzej Nowosielski, dr Jan Kisielewski, dr Jakub Zieliński, Marcin Semeniuk.
- Collaboration: dr hab. M. Rosińska, National Institute of Public Health, Governmental agencies: Government Centre for Security, Centre of Crisis Information CBK PAN, Centre of Strategic Analysis KPRM, Ministry of Health
- All computations are carried out using ICM UW computational resources (OKEANOS, RYSY).