RECOVER Closing Conference

Modelling the COVID-19 pandemic

Simon Cauchemez (Institut Pasteur)

6-7 June 2023

Esplanade Hotel, Zagreb, Croatia

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Contributions of modelling during the COVID-19 pandemic

- Estimating key parameters such as transmissibility and severity
- Evaluation of non-pharmaceutical and pharmaceutical interventions.
- Epidemic forecasting.

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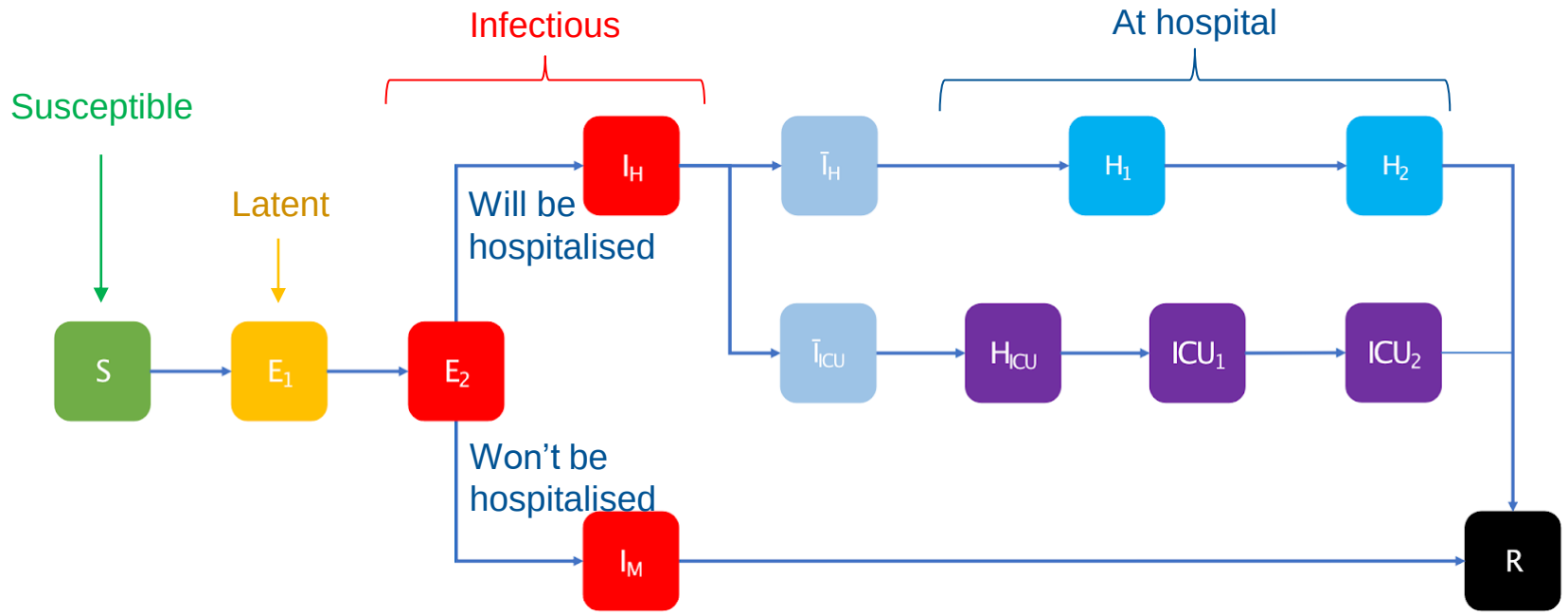
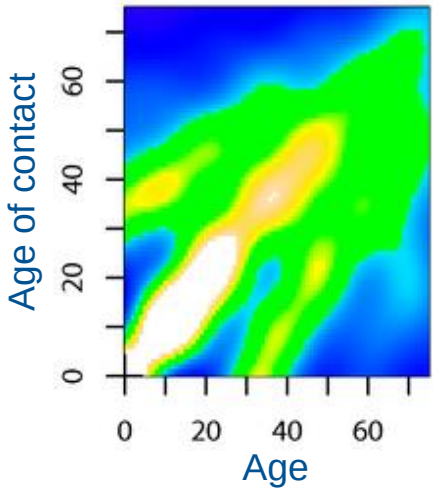
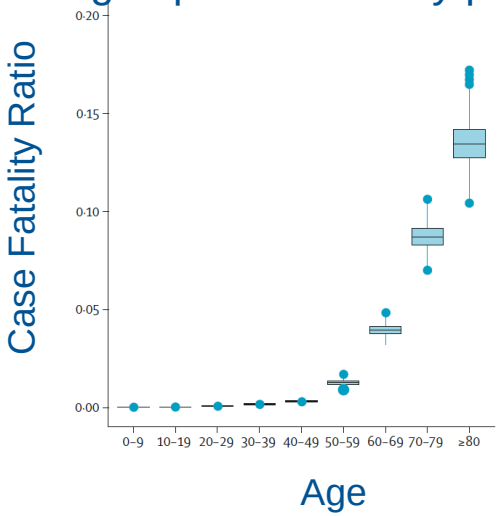
A first mathematical model to describe the spread of SARS-CoV-2 in France (Feb-March 2020)



Age-specific contact patterns



Age-specific severity profile



[Verity et al, Lancet ID, 2020; Béraud, PLoS One 2015]

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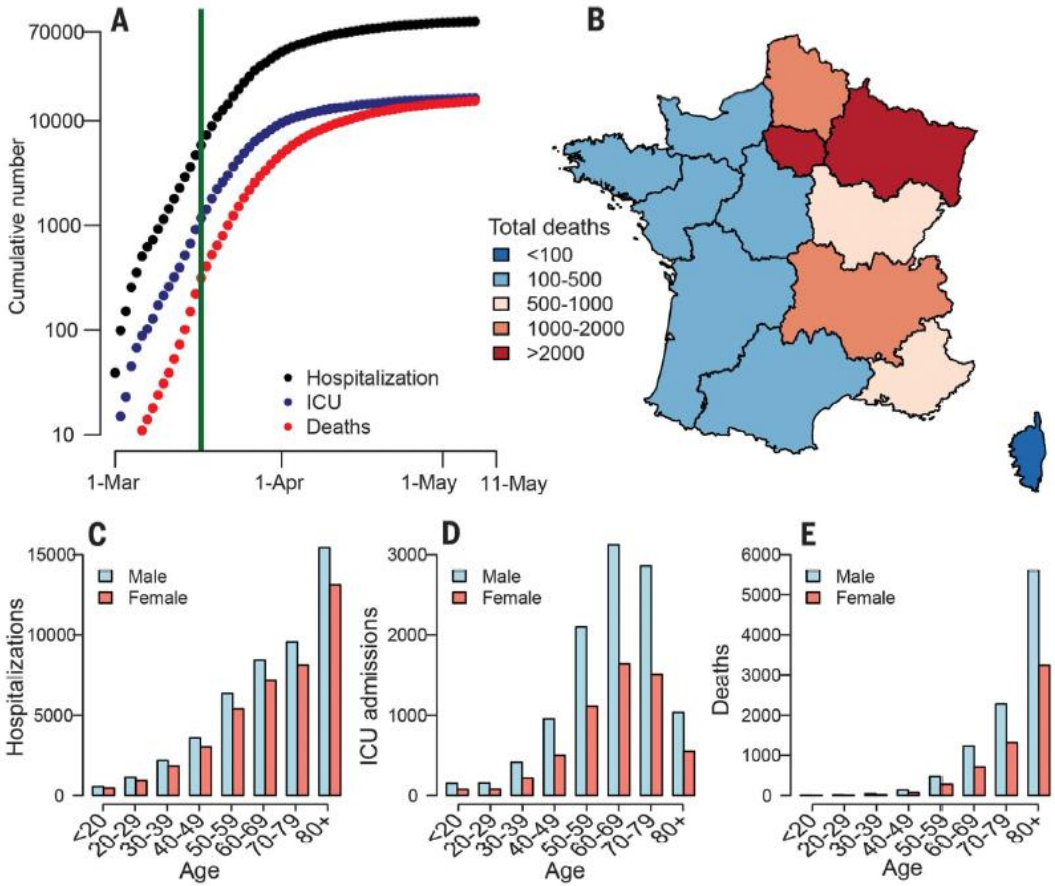
Estimating the scale of first pandemic wave in France
[Salje et al, Science 2020]

Passive hospital surveillance in France

95,000 hospitalisations and 16,000 hospital deaths on May 7th



Active surveillance in Diamond Princess

- 3711 passengers,
- 712 tested positive,
- 15 deaths

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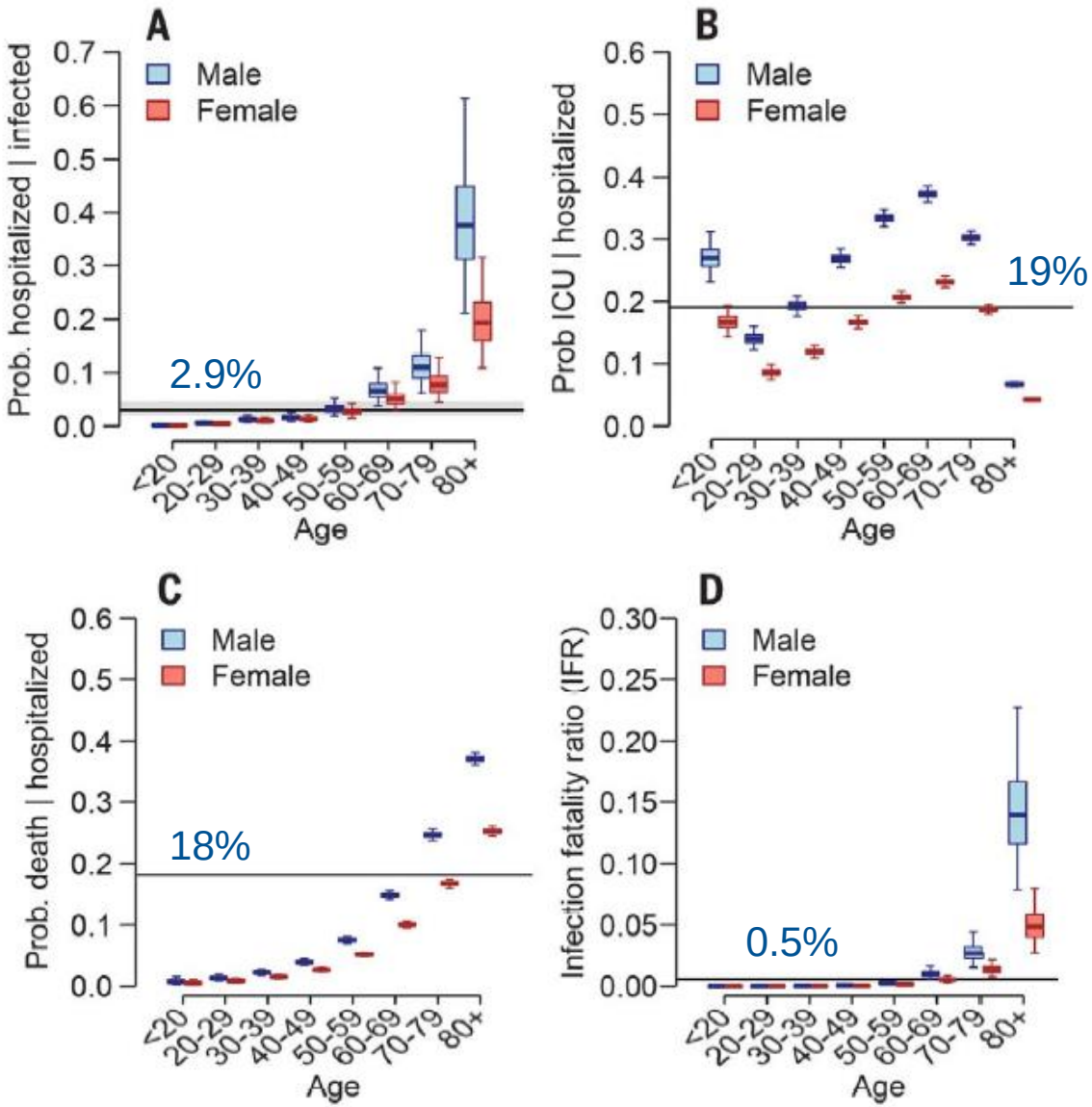
Estimates of risks by age group and sex



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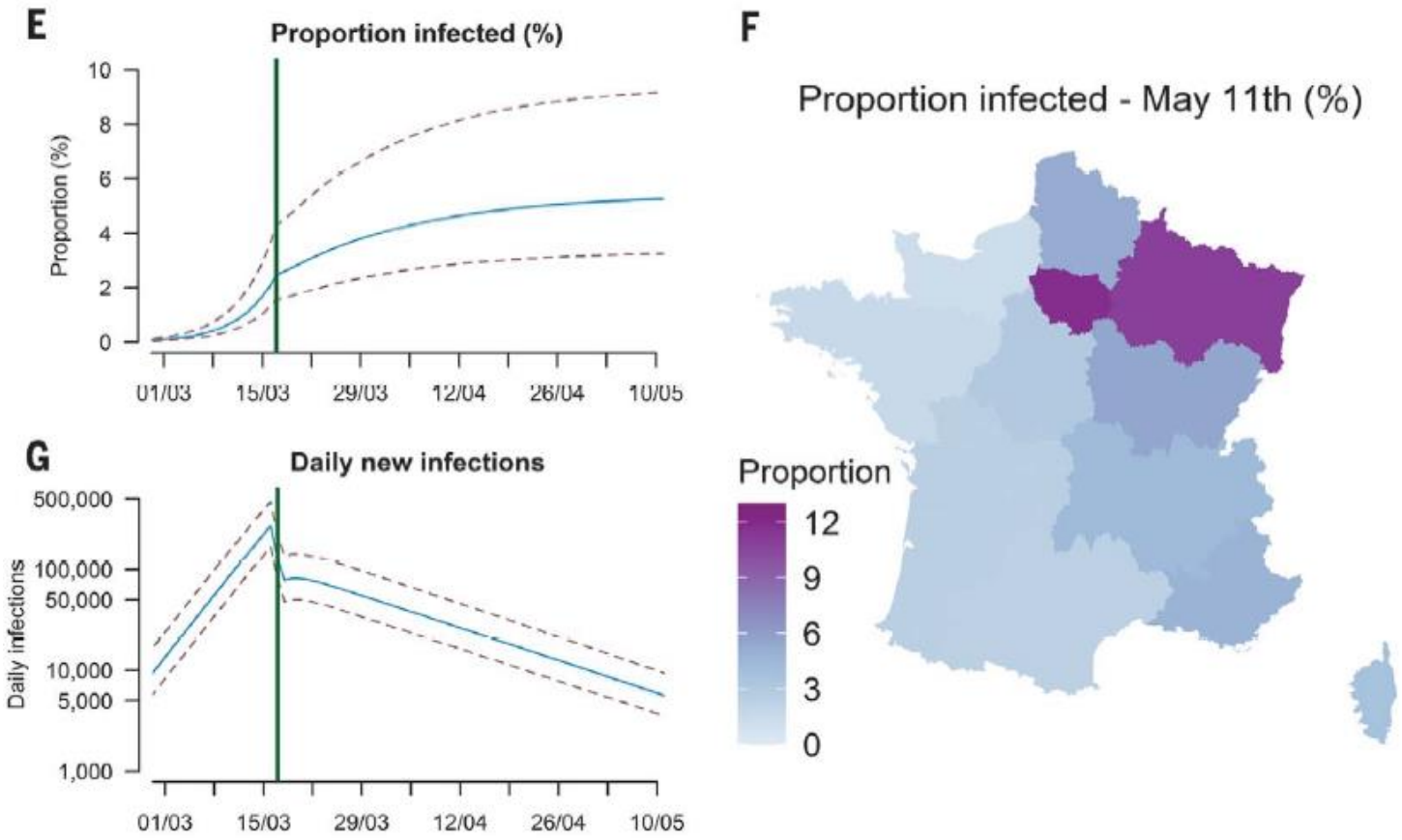
First estimates of the proportion infected after the first lockdown



Proportion infected on May 11th 2020:

- Nationally: 5.3% (3.3%-9.3%) ← Close to serosurveys (SpF) → 4.9%
- Ile de France: 11.9% (7.6%-19.4%)
- Grand Est: 10.9% (6.9%-18.1%)

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Assessing COVID-19 severity & proportion infected in 45 countries [O'Driscoll et al, Nature, 2020]

- Age stratified mortality data for 45 countries – 3.4 billion individuals
- 22 nationally representative seroprevalence studies from 16 countries

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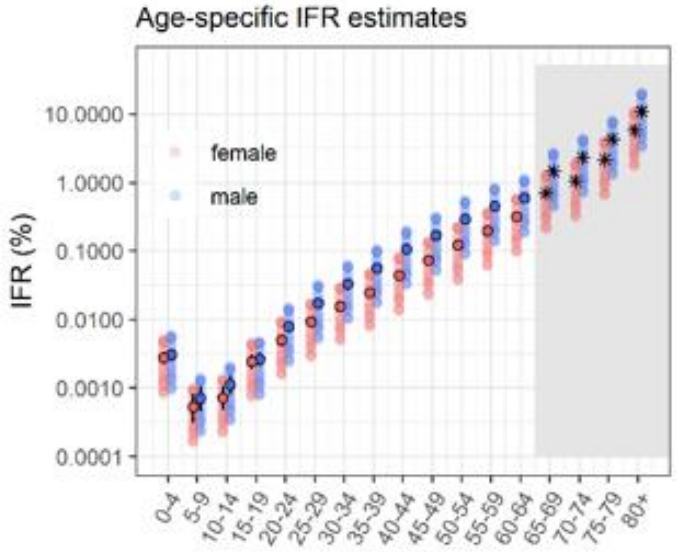
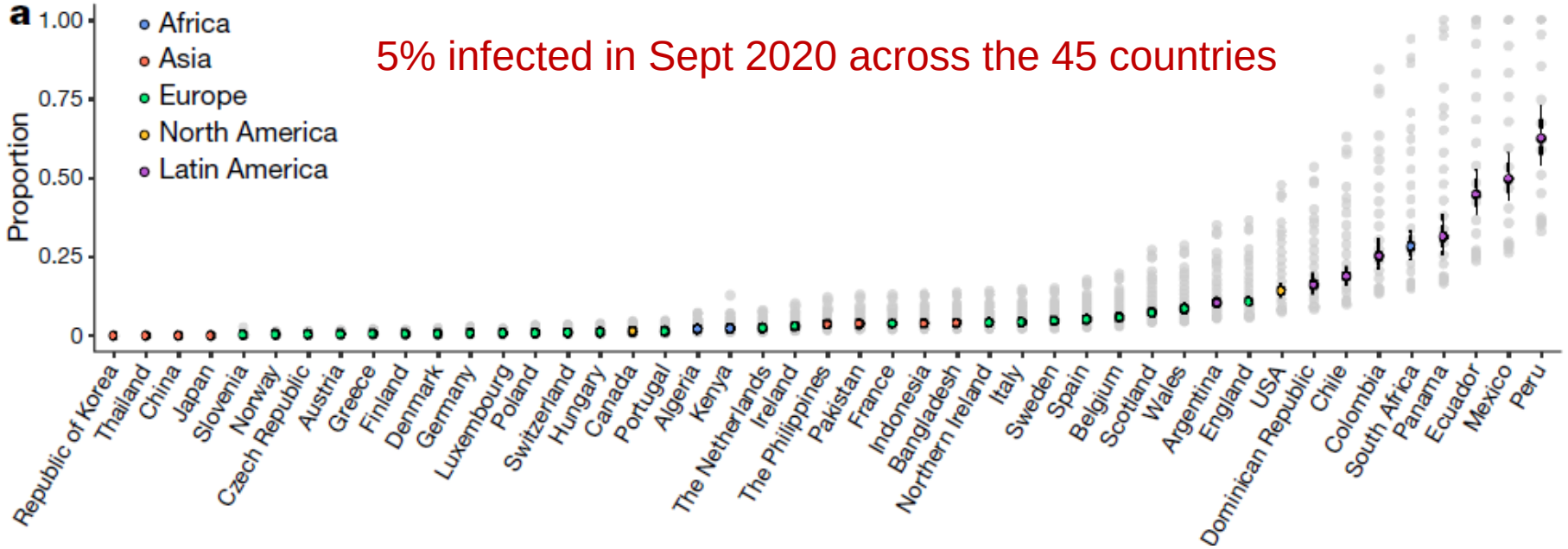
Assessing severity and proportion infected

Infection fatality ratio by age and sex



5% infected in Sept 2020 across the 45 countries



Anticipating and evaluating the impact of non-pharmaceutical measures and vaccination

Impact of lockdown
[Salje, Science; Cauchemez, Lancet]

Impact of curfews
[Andronico, Nat Com]

Isolation of the elderly
[Tran Kiem, Nat Com.]

Impact of mass testing
[Bosetti, Eurosurv.]

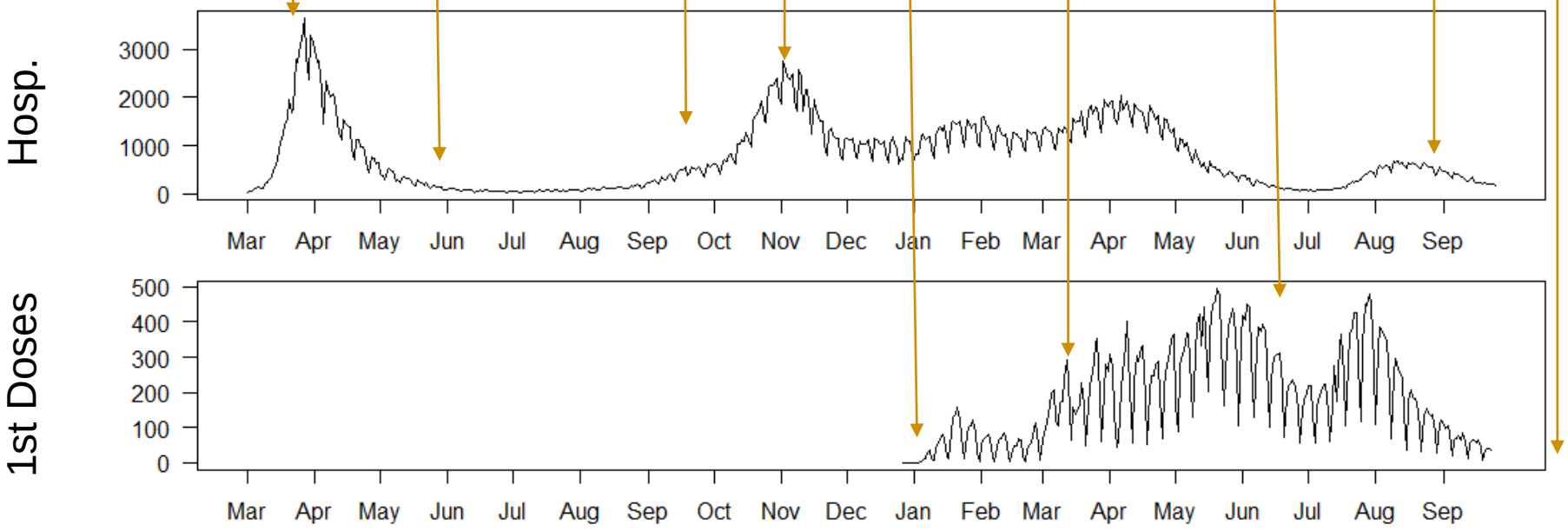
Prioritization strategy
[Tran Kiem, EClinMed]

Management of adverse events
[Tran Kiem, Eurosurv.]

Impact of vaccine coverage and sanitary Pass
[Bosetti, BMC Med]

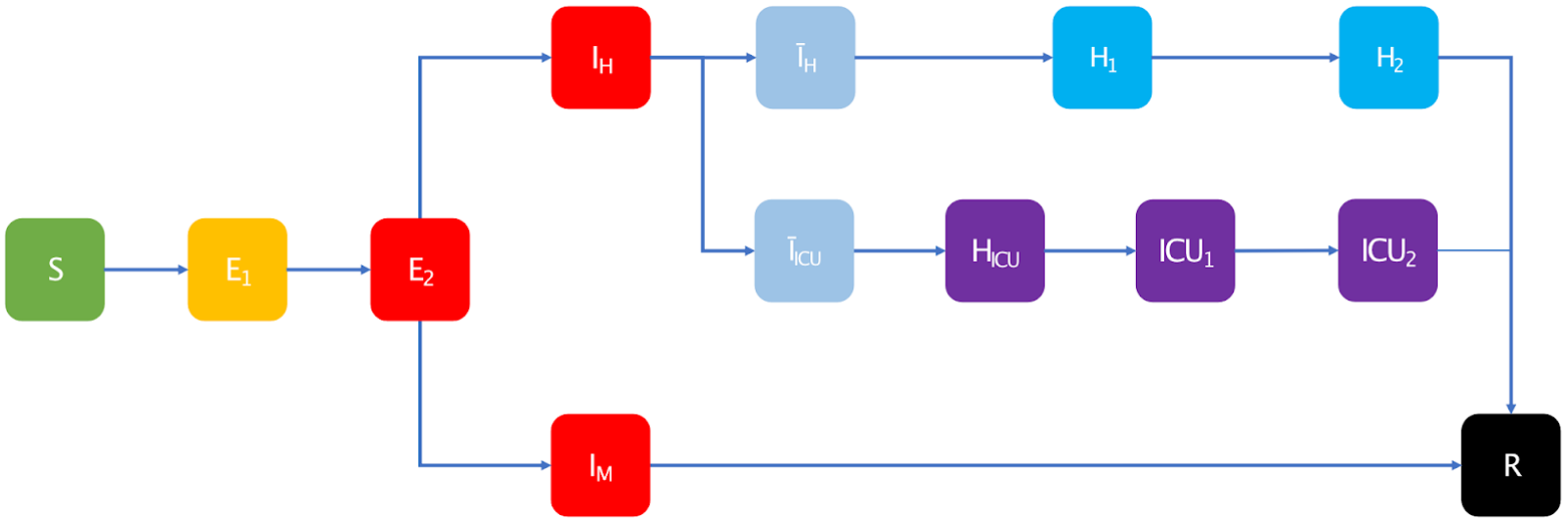
Role of boosters
[Bosetti, Eurosurv.]

Test and treat in Wallis and Futuna
[Brault, Lancet RH]



Improving short-term forecasts for healthcare planning
[Paireau et al, PNAS 2022]

- Initially, forecasts to support healthcare planning made with full transmission model, calibrated on hospitalisation data.
- But:
  - Hospitalization – late signal.
  - Do we need to model the full epidemic trajectory to forecast the next 2 weeks?



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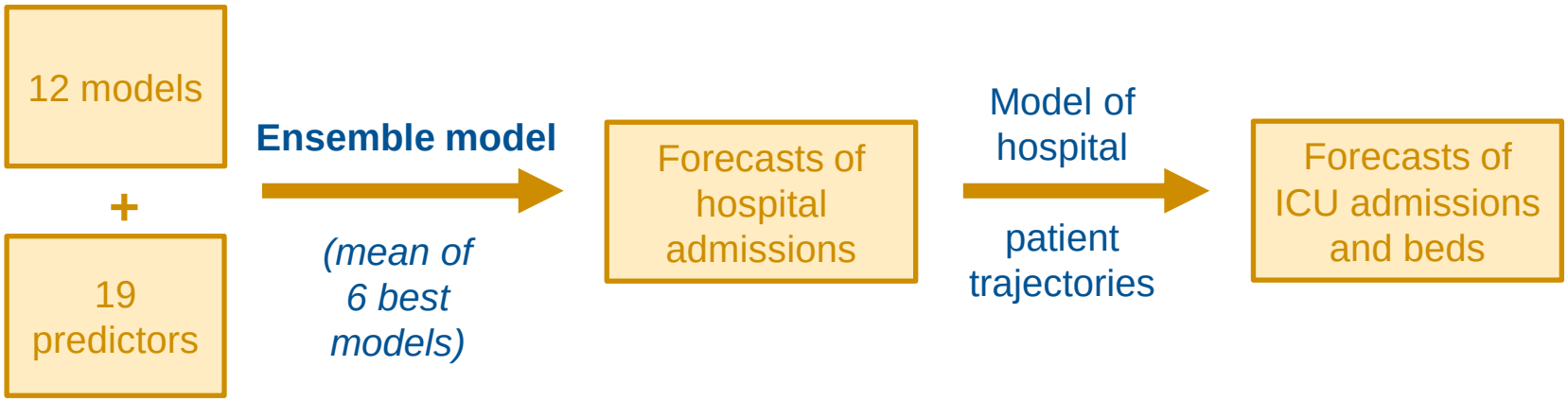
Systematic evaluation of models

- 12 individual models:
  - Number of hospital admissions (ARIMA, GAM)
  - Growth rate of the number of hospital admissions (constant, step function, stepwise linear, ARIMA, GAM, linear regression, BRT, RF)
- 19 predictors:
  - Mobility: Google
  - Epidemiological variables: growth rate of nb. positive cases, prop. positive tests…
  - Meteorological variables: température, humidité, IPTCC



Evaluation of the 12 models from September 7, 2020 to March 6, 2021
Test of the ensemble model from March 7, 2021 to July 6, 2021

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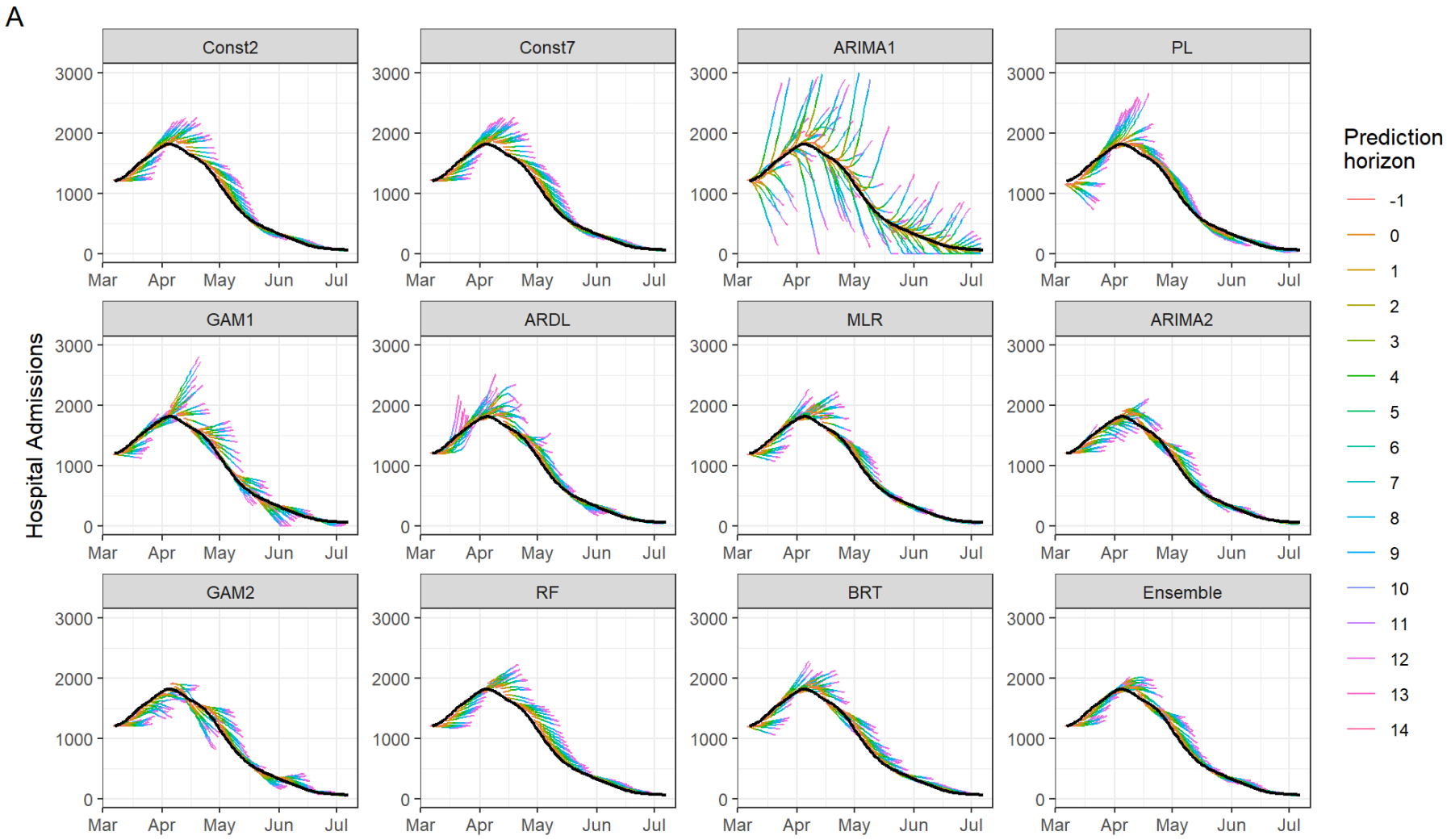
Comparing forecasting of different models



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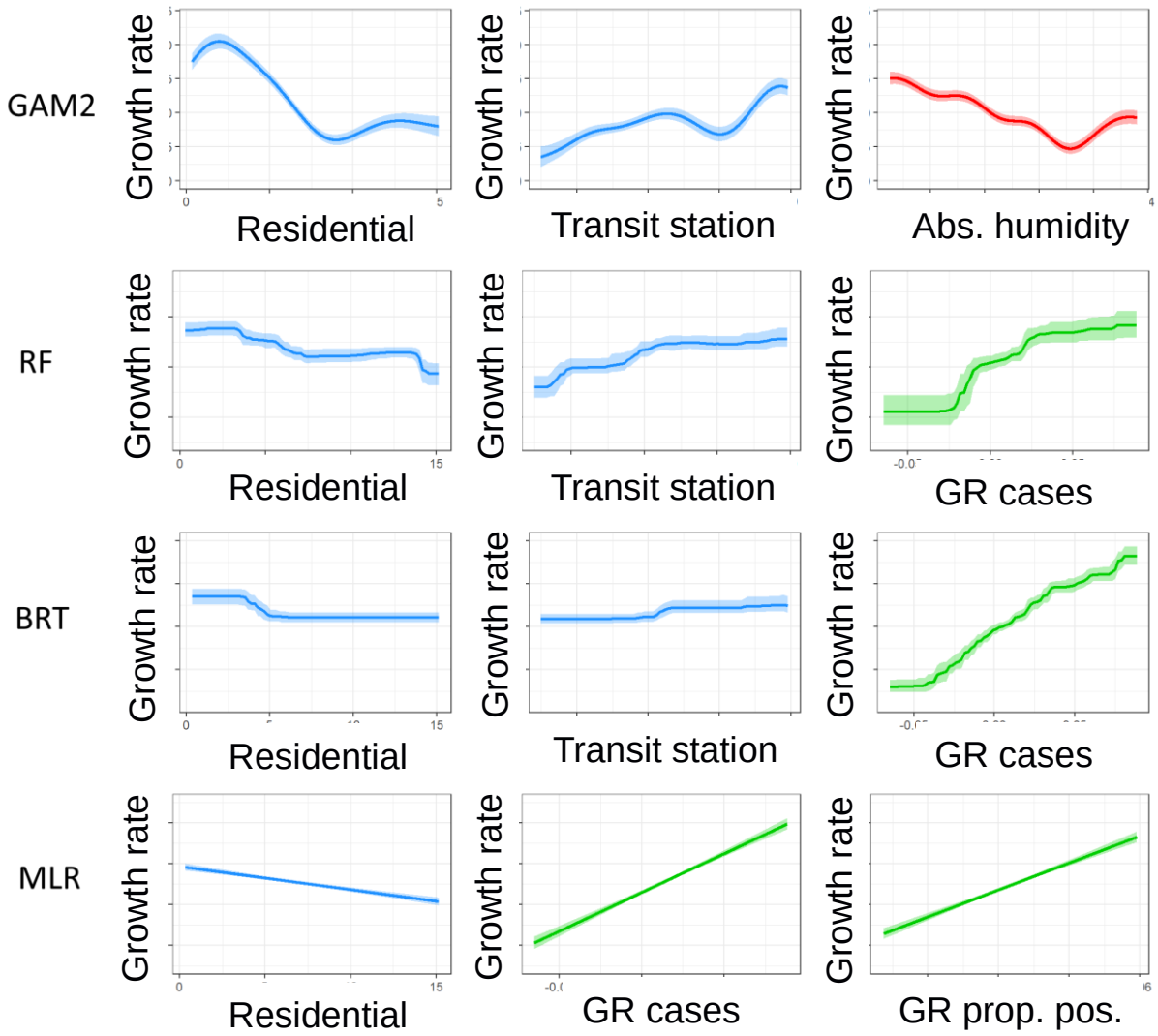
Predictors

Mobility

Epidemiological

Meteorological

Relative error of predictions 2 weeks ahead divided by two when predictors accounted for



On average, the ensemble model is the best model

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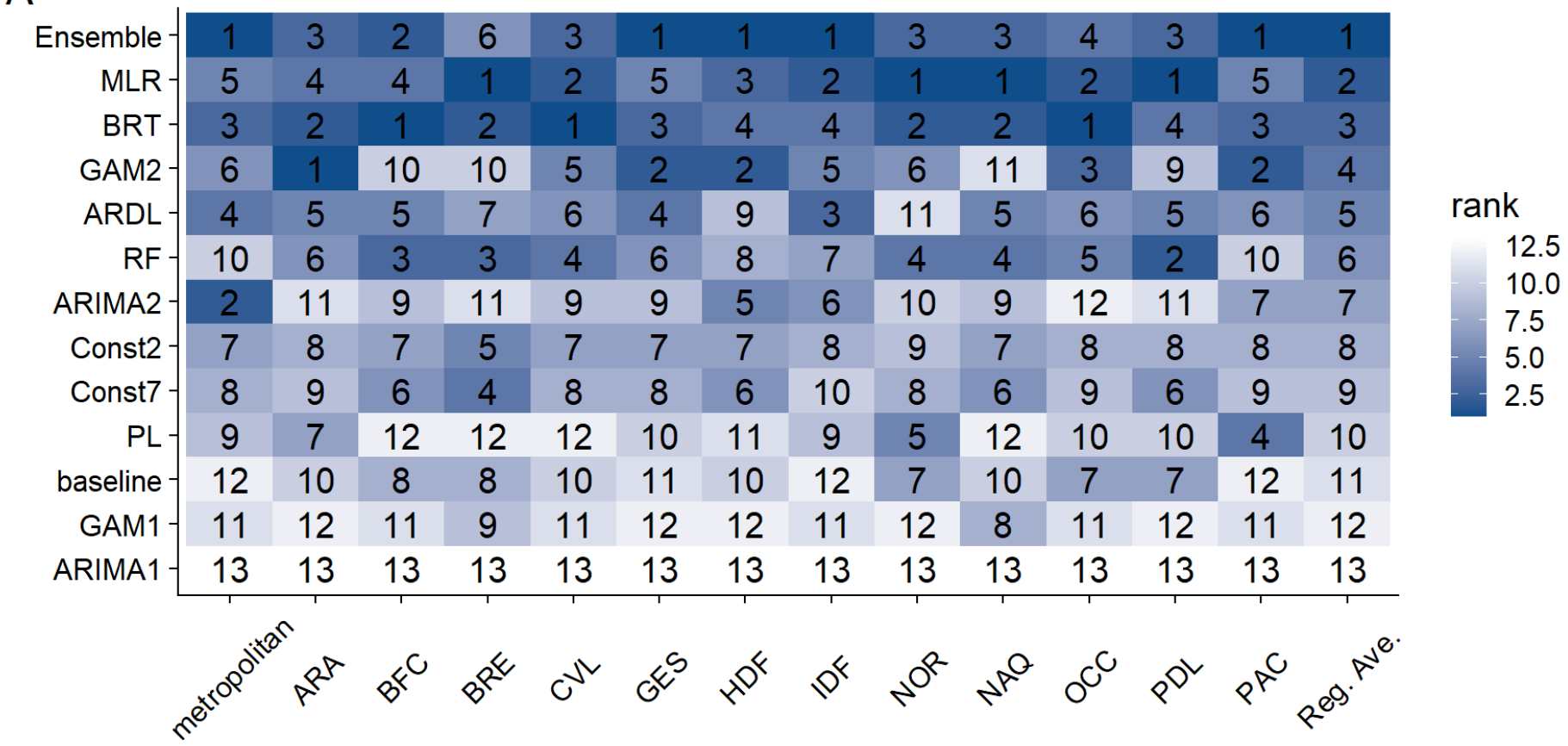

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COVID-19 modeling

Vittoria Colizza
INSERM, Paris, France

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6 - 7 June, 2023

Research directions

Surveillance

Social Distancing

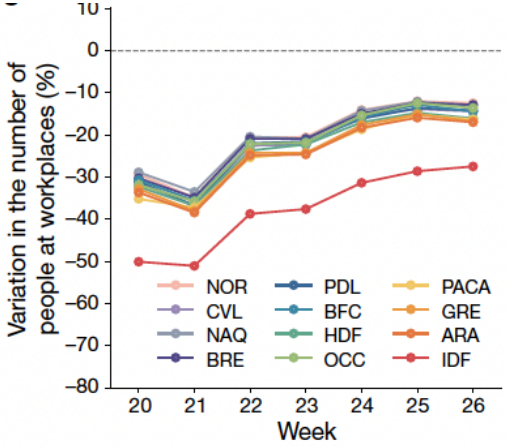
Spatial transmission

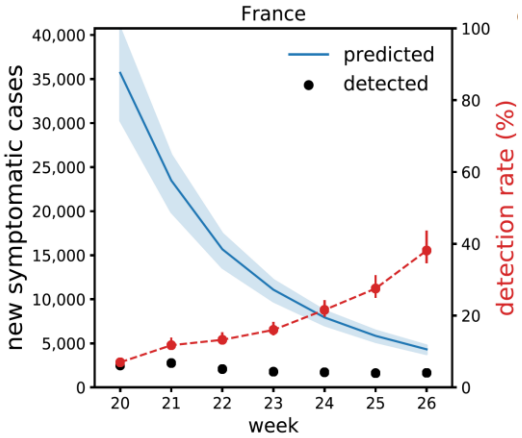
School transmission

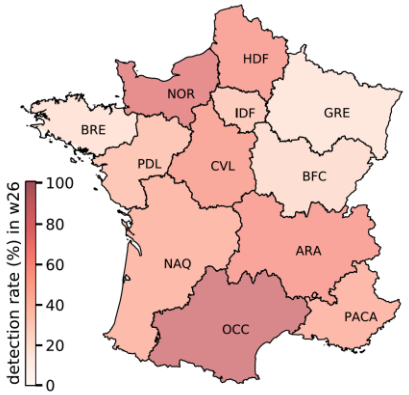
Surveillance

Quantifying spatial and temporal detection rates in the early phase

Exit phase from the first lockdown (May - June 2020)







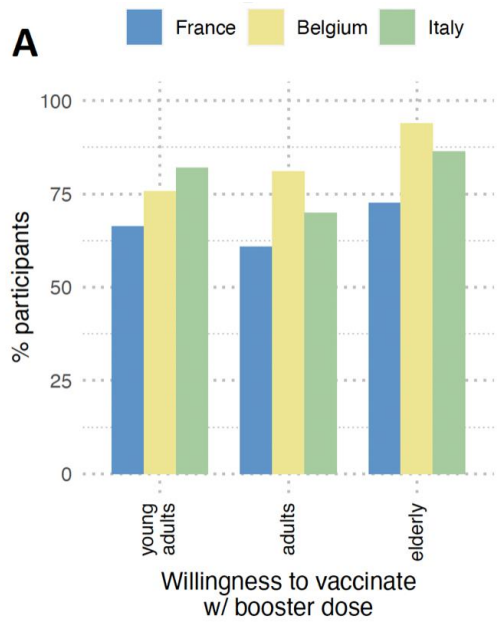
- Mobility data to parameterize synthetic contact matrices
- Participatory syndromic surveillance data (COVIDnet.fr) to assess suspect cases and health-seeking behavior

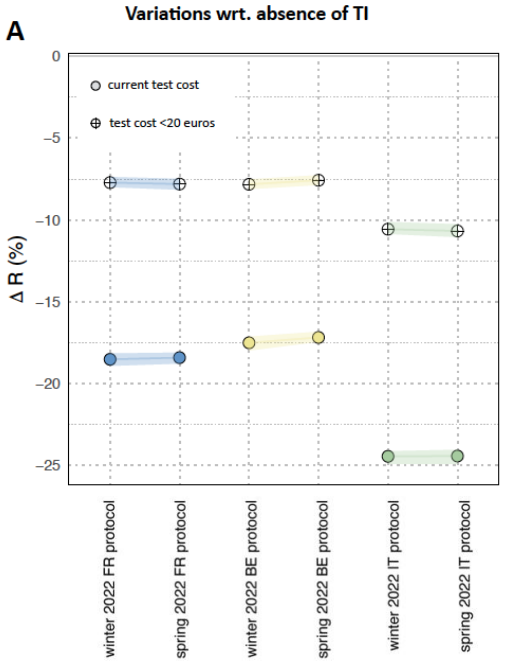
- 1 out of 10 symptomatic cases detected
- Limits in the surveillance system: lack of awareness, restricted access to test, limited testing of suspect cases

Pullano et al., Nature (2021)

Surveillance in the Omicron phase

Population attitudes towards booster vaccination, testing and isolation





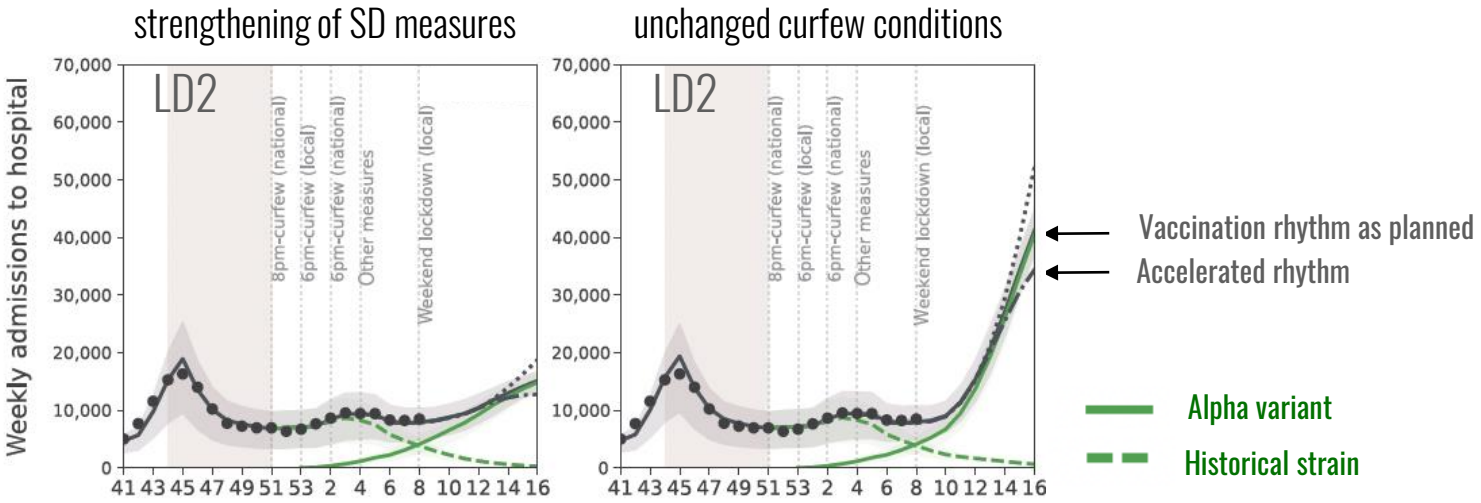
- Cost-effectiveness evaluation of testing-isolation protocols informed from multi-country survey data
- Simpler mandates for isolation may increase awareness and actual compliance, reducing testing costs, without compromising mitigation

De Meijere et al., Lancet Regional Health (2023)

Social distancing interventions & response

Impact of curfew on the Alpha wave

January - February 2021

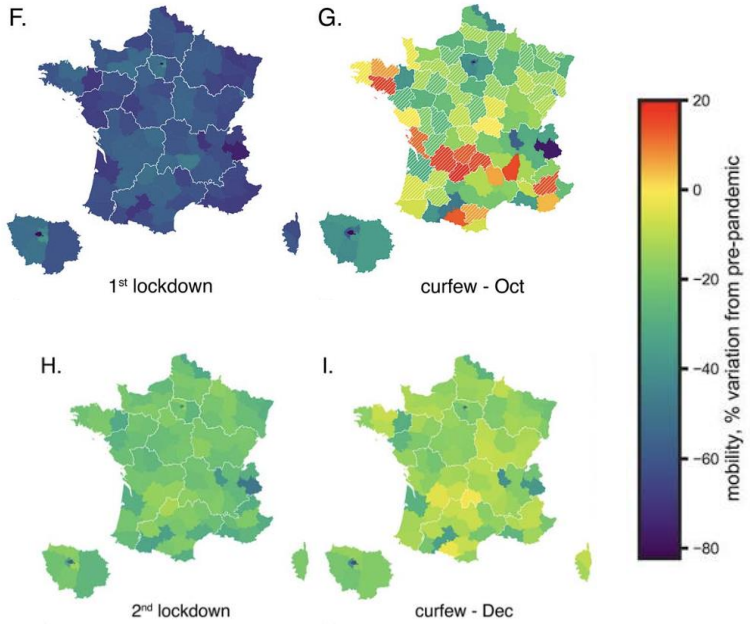


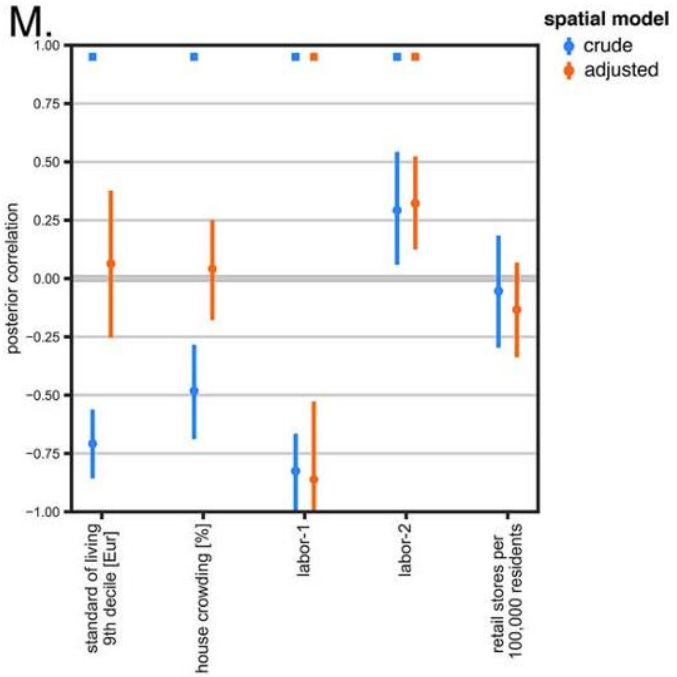
- curfew measures insufficient against Alpha variant
- in absence of strengthened measures, expected large wave despite acceleration in vaccination rhythm

Di Domenico et al., Eurosurveillance (2021)

Socio-economic constraints on population response to restrictions

Mobility during interventions in 2020





- Job market structure is a strong constraint in reducing mobility
  (higher proportion of white-collar jobs associated with higher mobility)

- Socio-economic factors can limit the effectiveness of movement restrictions and produce inequalities

Valdano et al., Journal of Travel Medicine (2021)

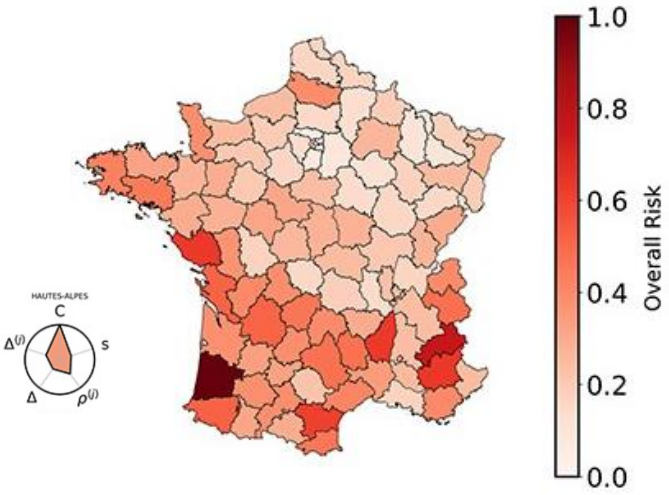
Spatial transmission

Spatial COVID-19 epidemic risk indicator

Delta summer wave 2021

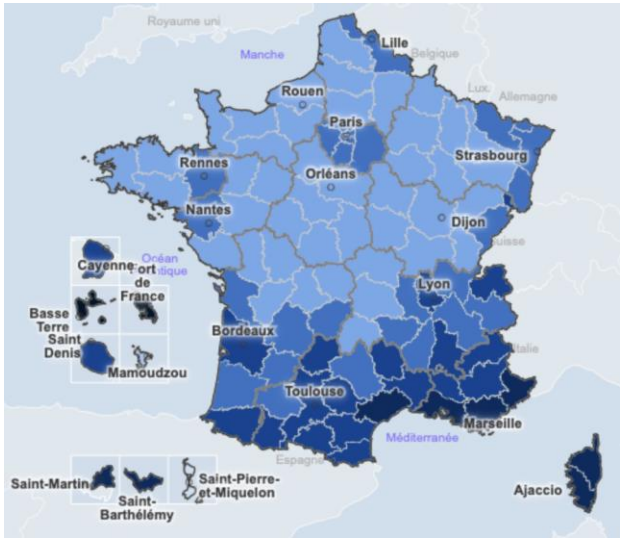
Prediction

With data from early July 2021



Data

Weekly incidence in early August 2021

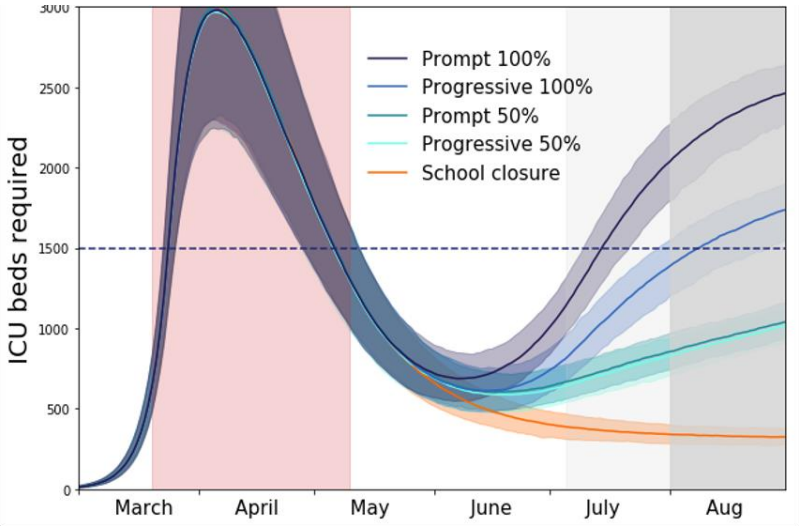


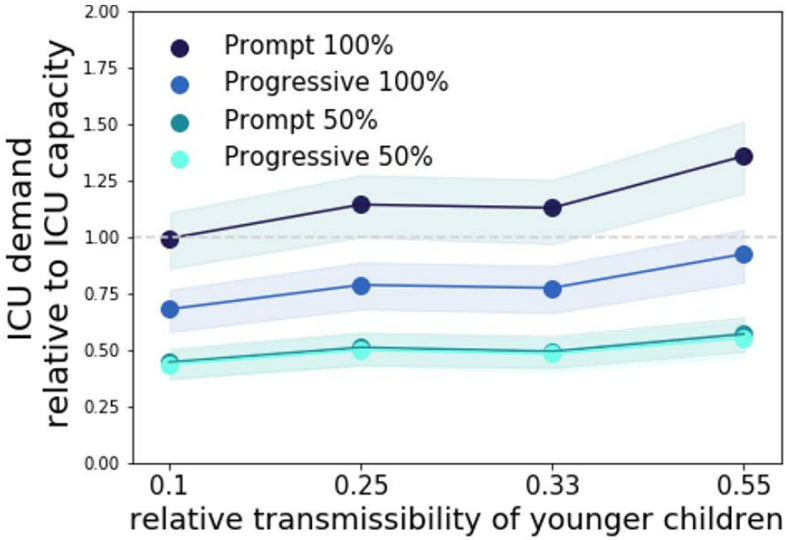
- Synthetic epidemic risk at dept level integrating immunity, crowding, presence of Delta variant, and exposure risk from neighbouring areas
- Identification of most at-risk depts for targeted interventions

Mazzoli et al., Journal of Travel Medicine (2021)

School transmission

Impact of school reopening after the first lockdown



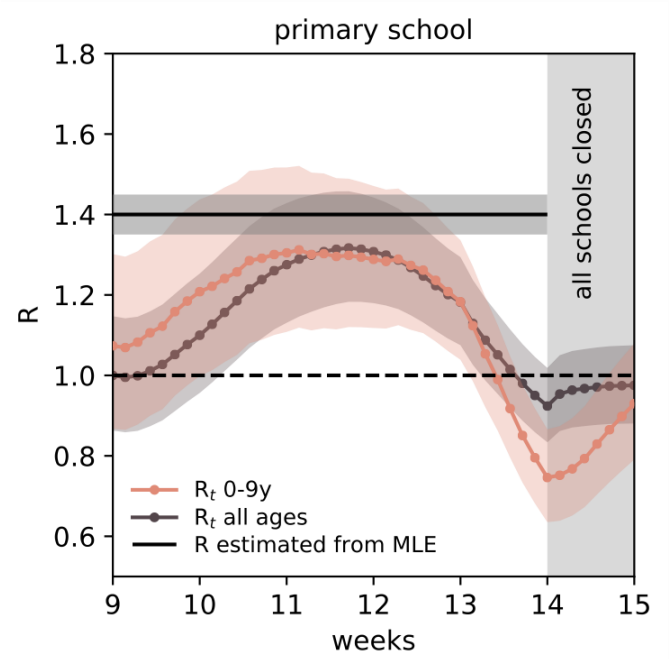


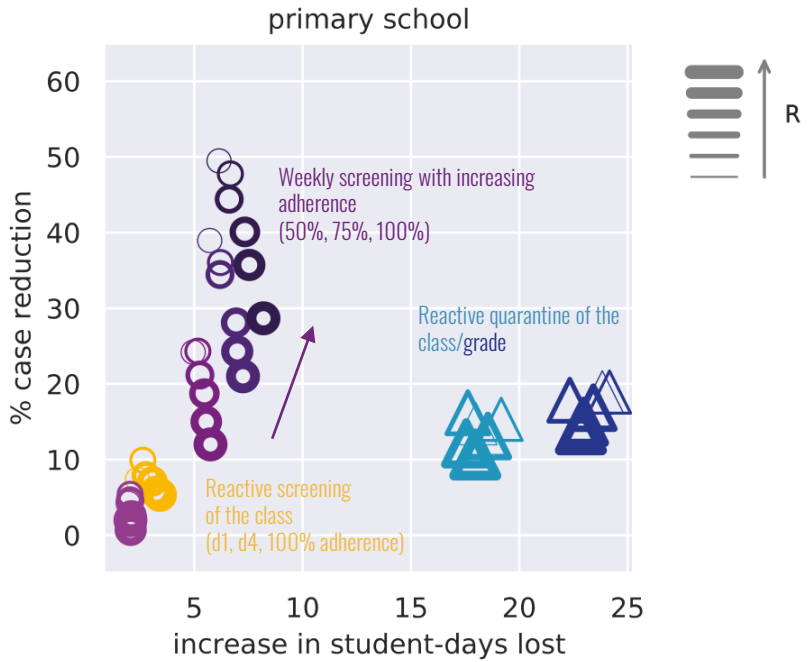
- Scenarios of partial, progressive or full school reopening
- Identification of safe reopening protocols despite uncertainty in transmissibility of younger children

Di Domenico et al., Nature Communications (2021)

School transmission and protocols comparison

Alpha wave, spring 2021 - Delta scenario, winter 2022



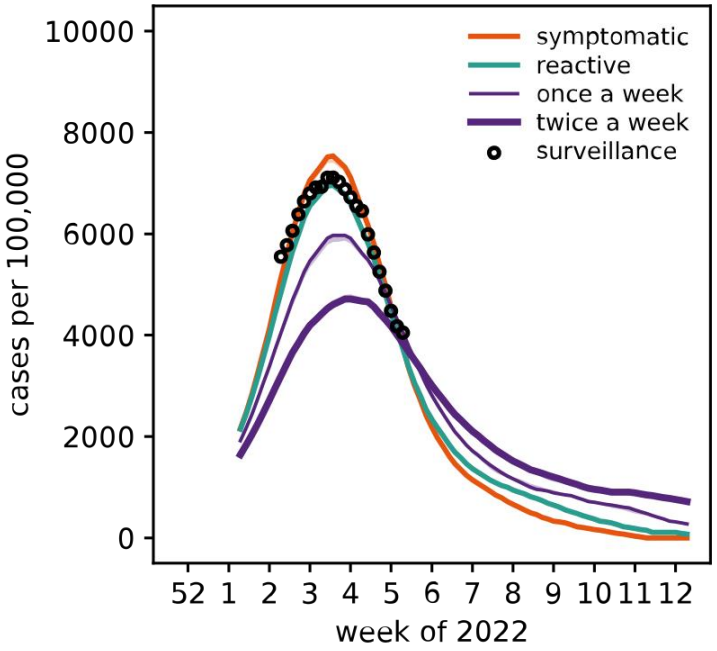


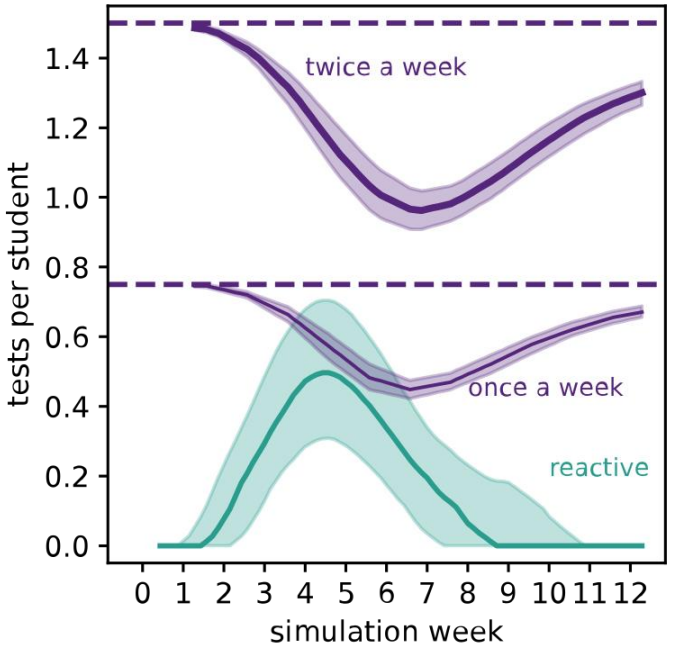
- R in schools larger than R in community
- Systematic screening can reduce the overall number of cases through the early detection and isolation of cases while avoiding unnecessary closures

Colosi et al., Lancet Infectious Diseases (2022)

Case prevention, test resources, days lost

Omicron wave, early 2022





- Under high incidence conditions, regular screening leads to a higher epidemic control with comparable use of resources w.r.t reactive screening

Colosi et al., Eurosurveillance (2023)

Impact/Output

- >50 publications in scientific journals, many more reports and forecasts.
- Supported risk assessments and recommendations of key health agencies in France: COVID-19 Scientific Committee, Santé Publique France (French CDC), French National Authority for Health, Regional Health Agencies, Direction Générale de la Santé, Direction Générale de l'Offre des Soins…
- With pandemic, modelling became a tool widely used by Public Health officials to inform decision making.

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Lessons learnt and recommendations - Communication

- Risk of misunderstanding of results by policy makers, with key scientific messages being « lost in translation »… and then miscommunication to the public;
- Need very close/regular/direct discussions between scientists and policy makers.
- Training of policy makers and end users. Developing understanding of what models can/can't do, strengths and limits, difference between scenario and forecast…
- Important to agree a framework for communication and that scientific messages are validated by scientists.

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Lessons learnt and recommendations - Data

- Key role of surveillance throughout the pandemic even later on e.g. monitoring of variants.
- Difficulty to monitor dynamics of infection. Importance of studies such as REACT and ONS in UK – such design should be applied in more countries in future epidemics.
- Data to understand spread in schools very difficult to get. To be improved for future pandemics.
- Difficulty to merge epidemiological datasets (e.g. on cases, hospitalisations, vaccinations, variants). To be improved for future pandemics.
- Some privately owned datasets (e.g. mobile phone datasets) remained difficult to access. Develop partnerships.

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Thank you MMMI team and collaborators!

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