COVIDHunter: An Accurate, Flexible, and Environment-Aware Open-Source COVID-19 Outbreak Simulation Model

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Executive Summary

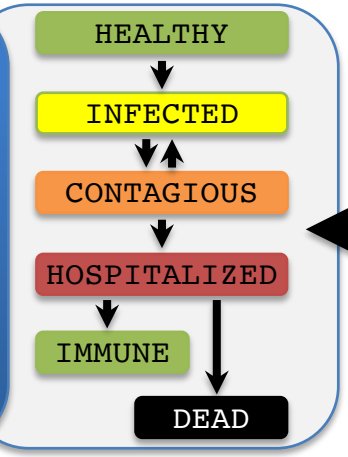
- **Problem:** No model is capable of accurately simulating the epidemiological situation while accounting for the effects of environmental conditions and considering a reasonably low number of assumptions and model parameters.
  - **No future prediction**: Accounting for reporting delays and under-reporting due to inefficiencies such as low number of COVID-19 tests.
  - **Inaccurate prediction**: Don't rely on the observed (laboratory-confirmed) number of cases, lack environment-awareness, and require a large number of assumptions and various input parameters.
- **Goal: Develop such a COVID-19 outbreak simulation model.**
- **COVIDHunter:**
  - **Key ideas:** Quantifies the spread of COVID-19 in a geographical region by calculating the daily **reproduction number**, R, based on 1) **mitigation measures**, 2) **environmental conditions**, 3) **population clustering** (`HEALTHY`, `INFECTED`, `CONTAGIOUS`, and `IMMUNE`), and 4) **infected travelers**.
  - Uses **historical** COVID-19 **hospitalizations-to-cases** and **deaths-to-cases ratios** for calculating the number of hospitalizations and deaths.
- **Key results:**
  - Compared to prominent policy-making models (IBZ, LSHTM, ICL, and IHME), COVIDHunter achieves more accurate estimation and provides no prediction delay.
  - For each 1◦C rise in daytime temperature, there is a 3.67% decrease in the daily number of confirmed cases.
  - COVIDHunter is easy to use and flexible to configure due to the simple modeling approach that uses a small number of parameters.

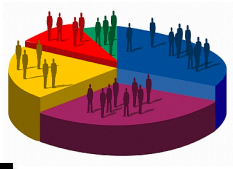
How Does COVIDHunter Work?

Mitigation measures & environmental conditions

Predict the daily R value

Label each individual





Population statistics and number of infected travelers

Predict the daily number of cases

Predict the daily number of hospitalizations and deaths

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R describes the **average number** of new infections caused by each **infected person**

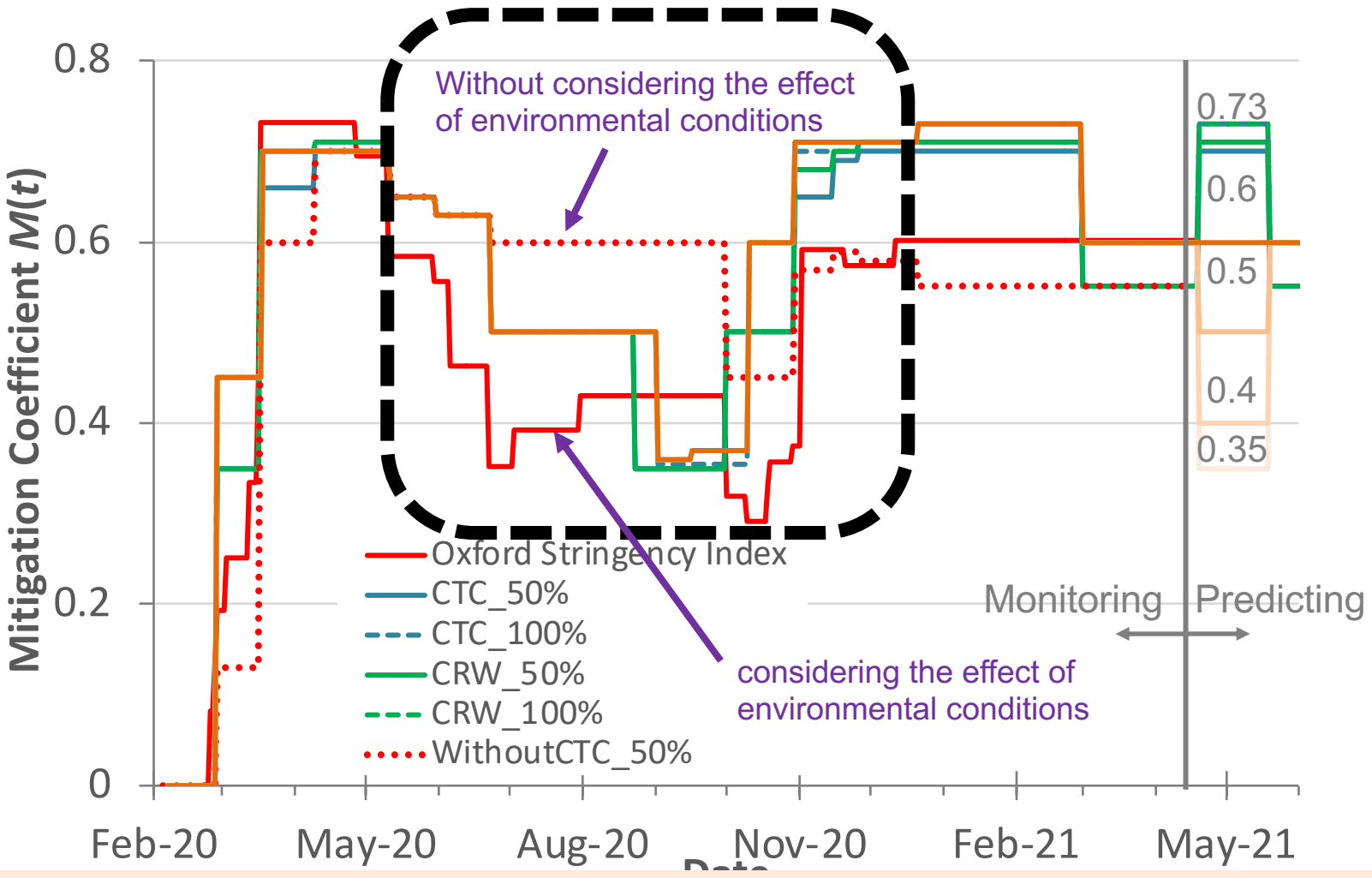
Epidemiological Situation in Switzerland

- **We use Switzerland as a use-case for all the experiments.**
  - COVIDHunter is completely configurable for other countries:
  - https://github.com/CMU-SAFARI/COVIDHunter/tree/main/Reproduce-Switzerland-Case-Study-Results

- **Workloads**
  - Data and source code: https://github.com/CMU-SAFARI/COVIDHunter
  - Simulation runs and visualization: https://mealser.github.io/COVIDHunter/

- **Comparison points**
  - Prominent simulation models used to assist in decision-making for policy-makers in countries:
    - » **United Kingdom, ICL** [Flaxman+, Nature 2020].
    - » **United States, IHME** [Reiner+, Nature Medicine 2020].
    - » **Switzerland, IBZ** [Huisman+, medRxiv 2020]
    - » **LSHTM** [Russell+, BMC Medicine 2020].

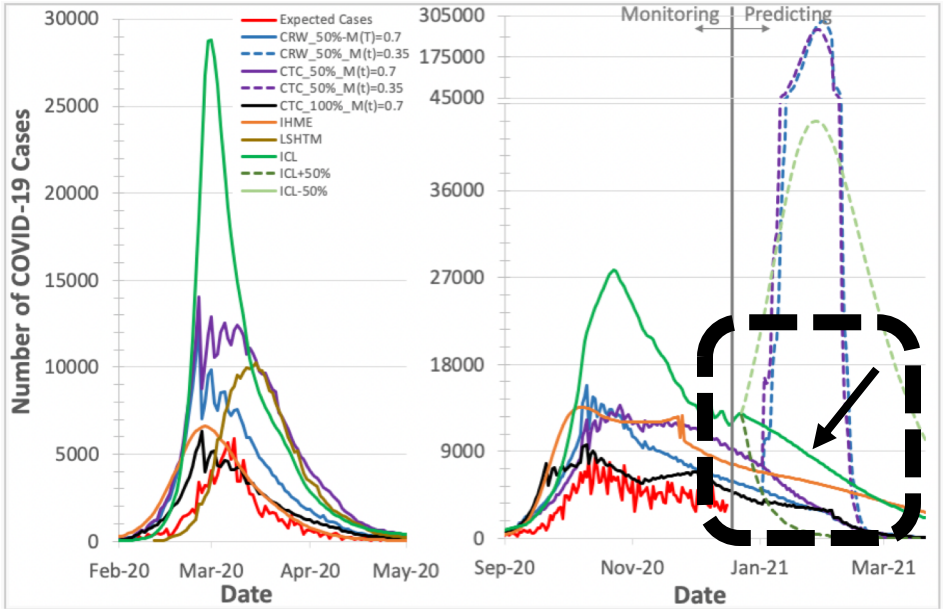
Evaluating the Mitigation Measures



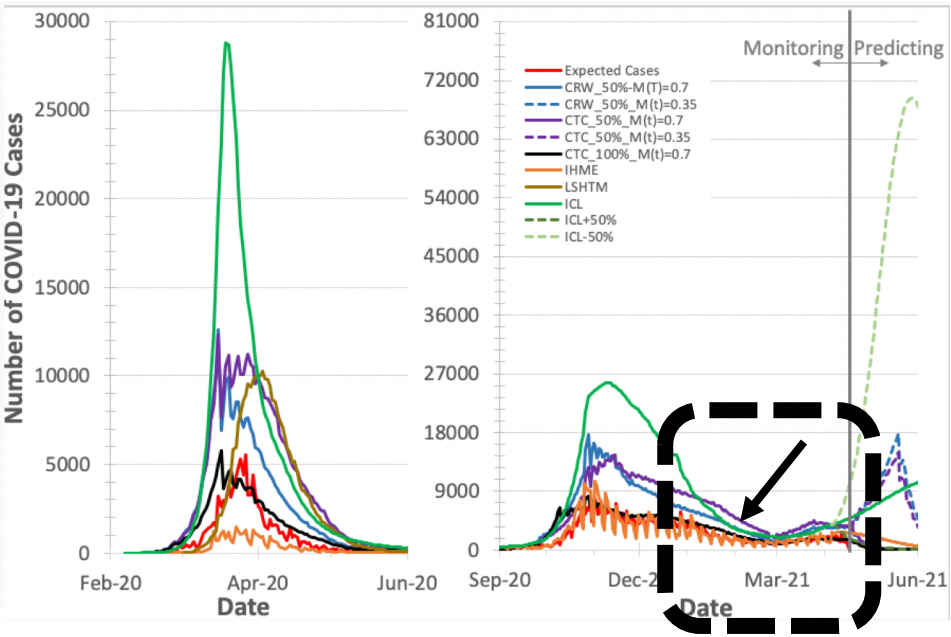
Mitigation measures applied **during the summer** of 2020 are **only 14% more relaxed** compared to the mitigation measures applied **during the first wave**, which is **implausible**.

Predicted Number of COVID-19 Cases

Simulation run: January 2021



Simulation run: April 2021



ICL model provides **overestimated number of COVID-19 cases** (3.8× compared to `CTC_100%_M(t)=0.7`) as demonstrated using **two different simulation runs**, January 2021 and April 2021.

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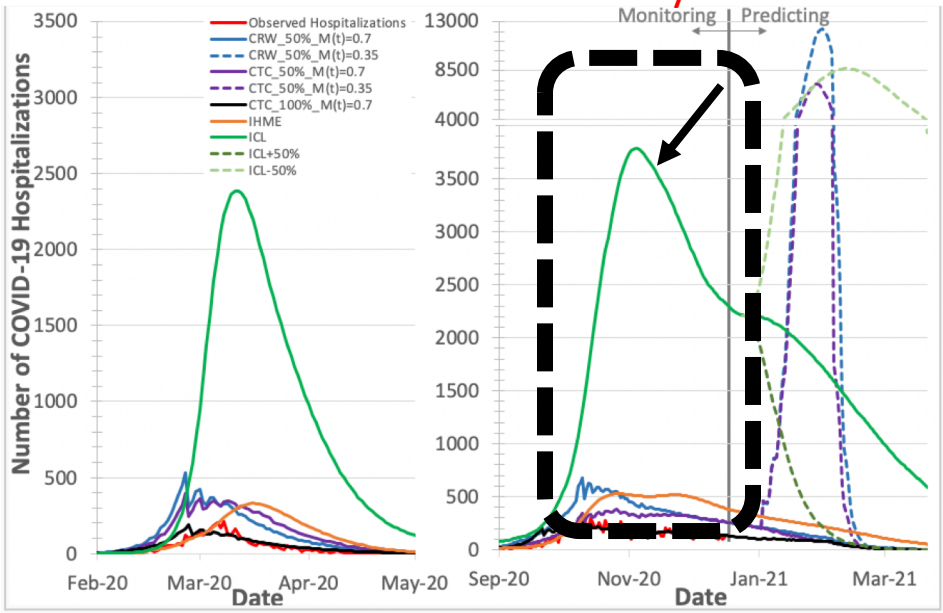
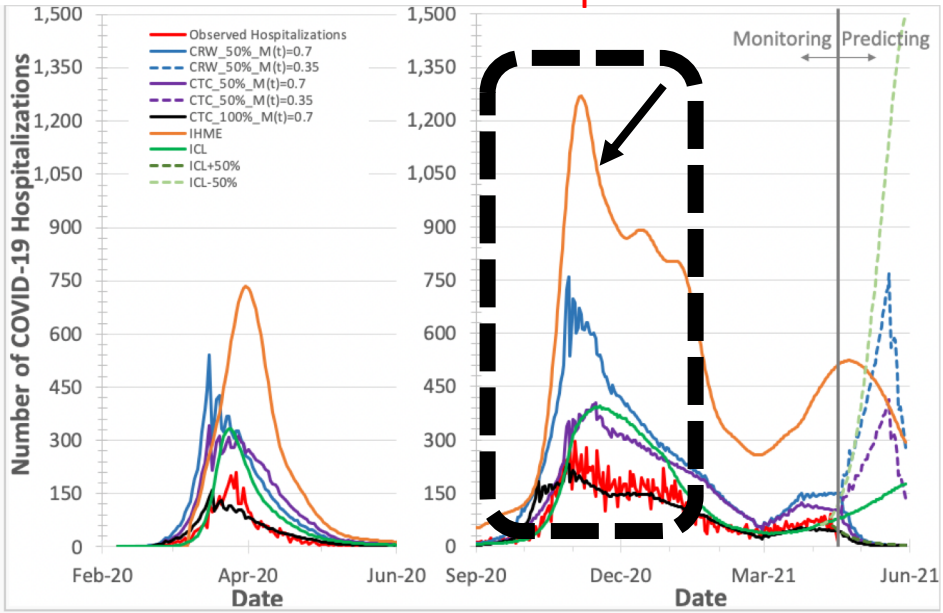
Predicted Number of COVID-19 Hospitalizations

Simulation run: January 2021



Simulation run: April 2021



ICL model and **IHME** model **overestimate the number of hospitalizations** (18.6× and 10.6× higher than the observed number of hospitalizations), **using January and April 2021 simulation runs**, respectively, which is **highly unlikely**.

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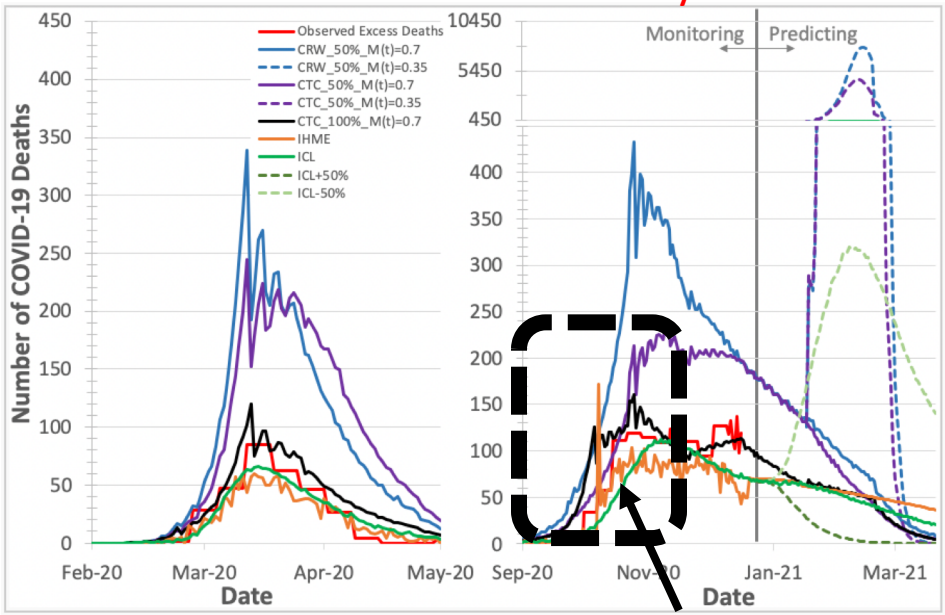
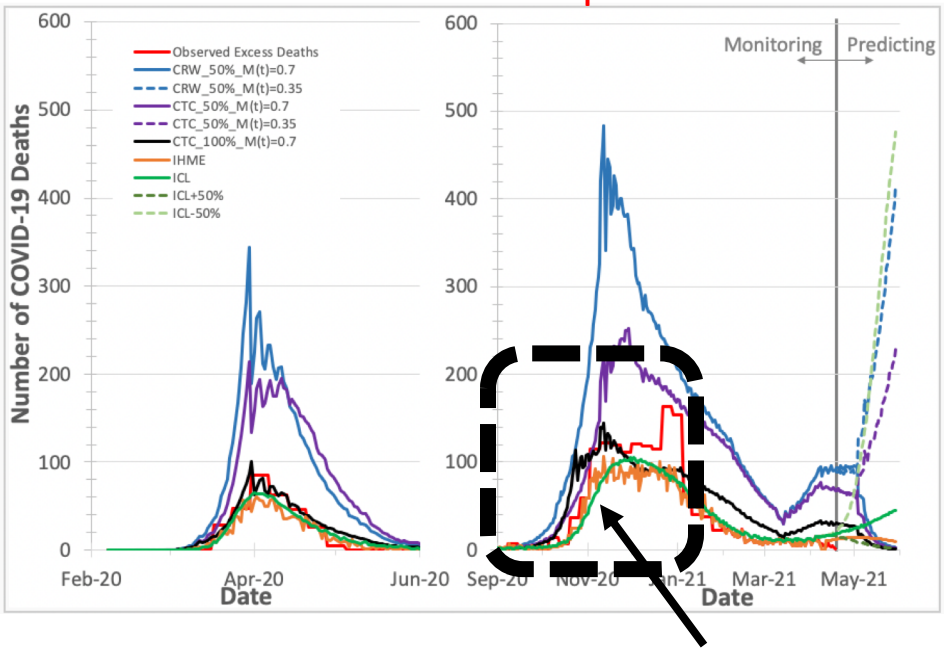
Predicted Number of COVID-19 Deaths

Simulation run: January 2021



Simulation run: April 2021



ICL and IHME models provide **late prediction** (their curves are shifted by 5-10 days from that of other models).

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COVIDHunter 2.0

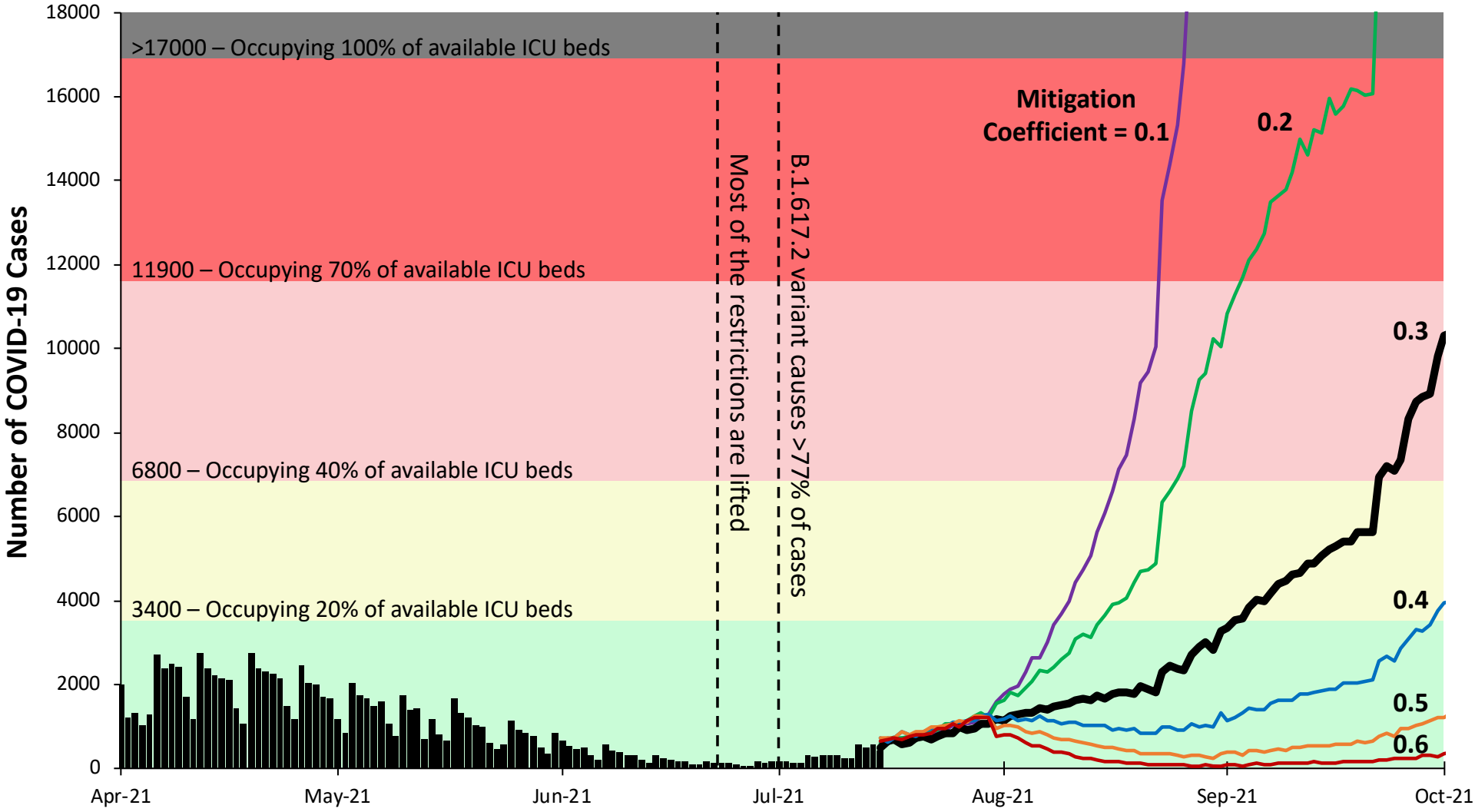
- Support for a mutated virus with a different R0 value.
- Support for asymptomatic cases.
- Support for vaccinations.

- Compatible with **COVIDHunter 1.0**
  - The reproduction number, R.
  - The number of infected persons.
  - The number of hospitalized persons.
  - The number of deaths.
  - The number of individuals at each stage of the COVID-19 infection (healthy, infected, contagious, and immune).
  - The strength and the duration of each mitigation measure.

https://github.com/CMU-SAFARI/COVIDHunter

The Summer of 2021 is different in Switzerland

The effect of changing the strength of the mitigation measures applied in Switzerland during August 2021



COVIDHunter forecasts that **further tightening** of mitigation measures is needed before **October 2021** to avoid overwhelming healthcare system in Switzerland.

https://github.com/CMU-SAFARI/COVIDHunter

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Data	Update README.md	4 months ago
Evaluation_Results	Update README.md	
Reproduce-Switzerland-Case-Stu...	Update README.md	
TemperatureSensitivityStudy	Update README.md	
src	Update README.md	
LICENSE	Initial commit	
README.md	Update README.md	

README.md

COVIDHunter: An Accurate, Flexible, ar

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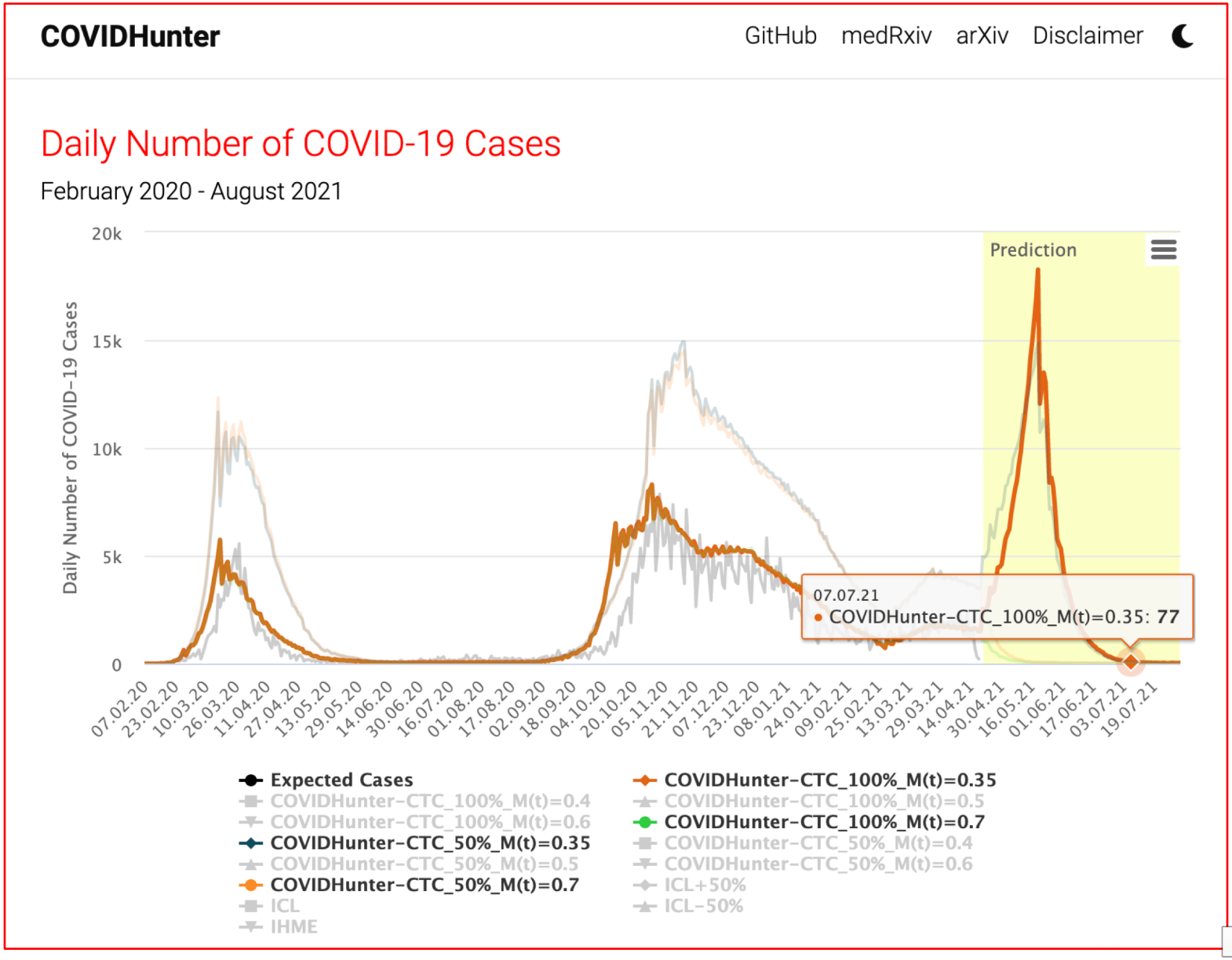

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Alser+, COVIDHunter: An Accurate, Flexible, and Environment-Aware Open-Source COVID-19 Outbreak Simulation Model, medRxiv, 2021

Source code: https://github.com/CMU-SAFARI/COVIDHunter
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