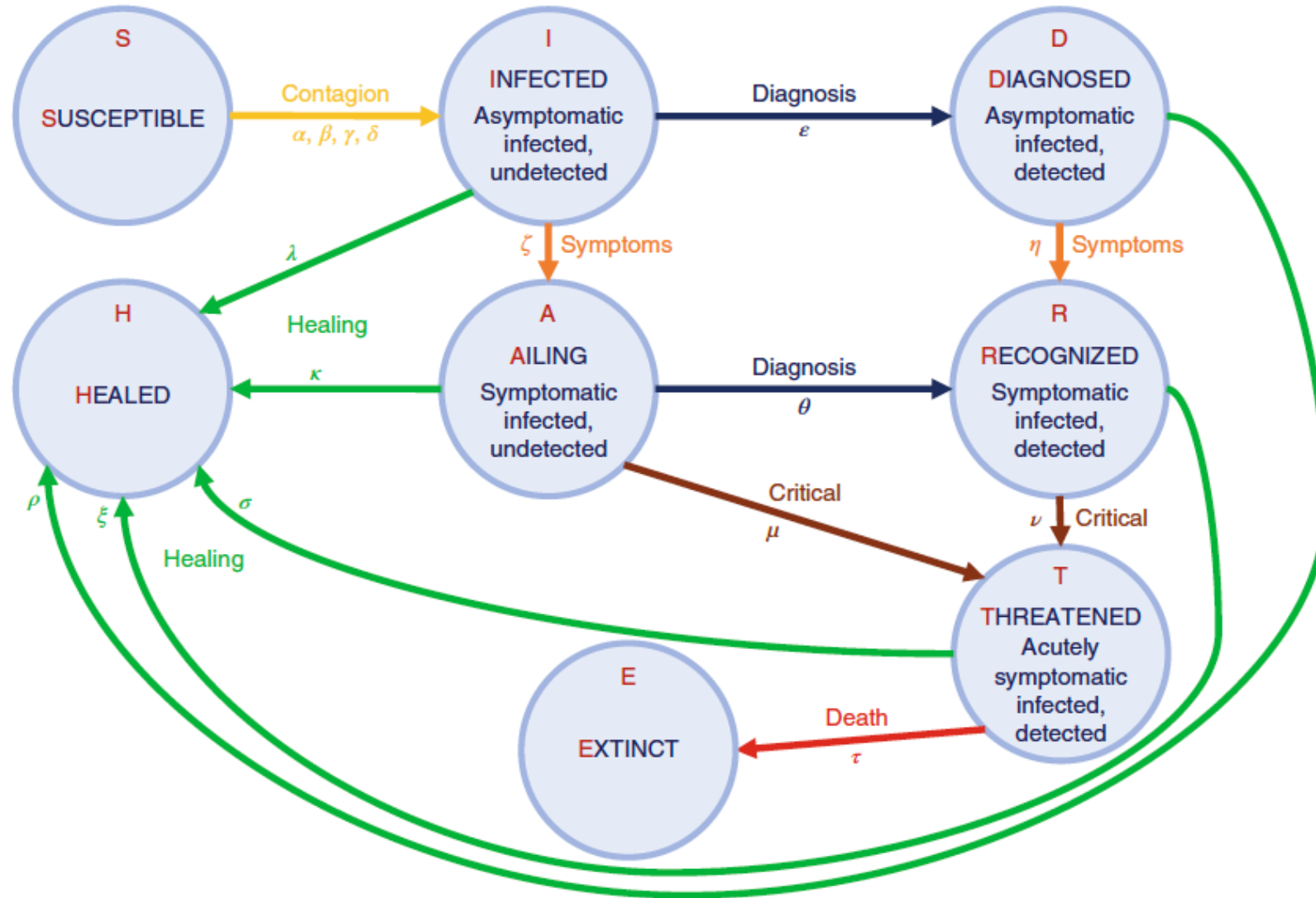


Modeling Covid-19 data from African Countries

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The Model



Methods

SIDARTHE mathematical model. The SIDARTHE dynamical system consists of eight ordinary differential equations, describing the evolution of the population in each stage over time:

$$\dot{S}(t) = -S(t)(\alpha I(t) + \beta D(t) + \gamma A(t) + \delta R(t)) \quad (1)$$

$$\dot{I}(t) = S(t)(\alpha I(t) + \beta D(t) + \gamma A(t) + \delta R(t)) - (\epsilon + \zeta + \lambda)I(t) \quad (2)$$

$$\dot{D}(t) = \epsilon I(t) - (\eta + \rho)D(t) \quad (3)$$

$$\dot{A}(t) = \zeta I(t) - (\theta + \mu + \kappa)A(t) \quad (4)$$

$$\dot{R}(t) = \eta D(t) + \theta A(t) - (\nu + \xi)R(t) \quad (5)$$

$$\dot{T}(t) = \mu A(t) + \nu R(t) - (\sigma + \tau)T(t) \quad (6)$$

$$\dot{H}(t) = \lambda I(t) + \rho D(t) + \kappa A(t) + \xi R(t) + \sigma T(t) \quad (7)$$

$$\dot{E}(t) = \tau T(t) \quad (8)$$

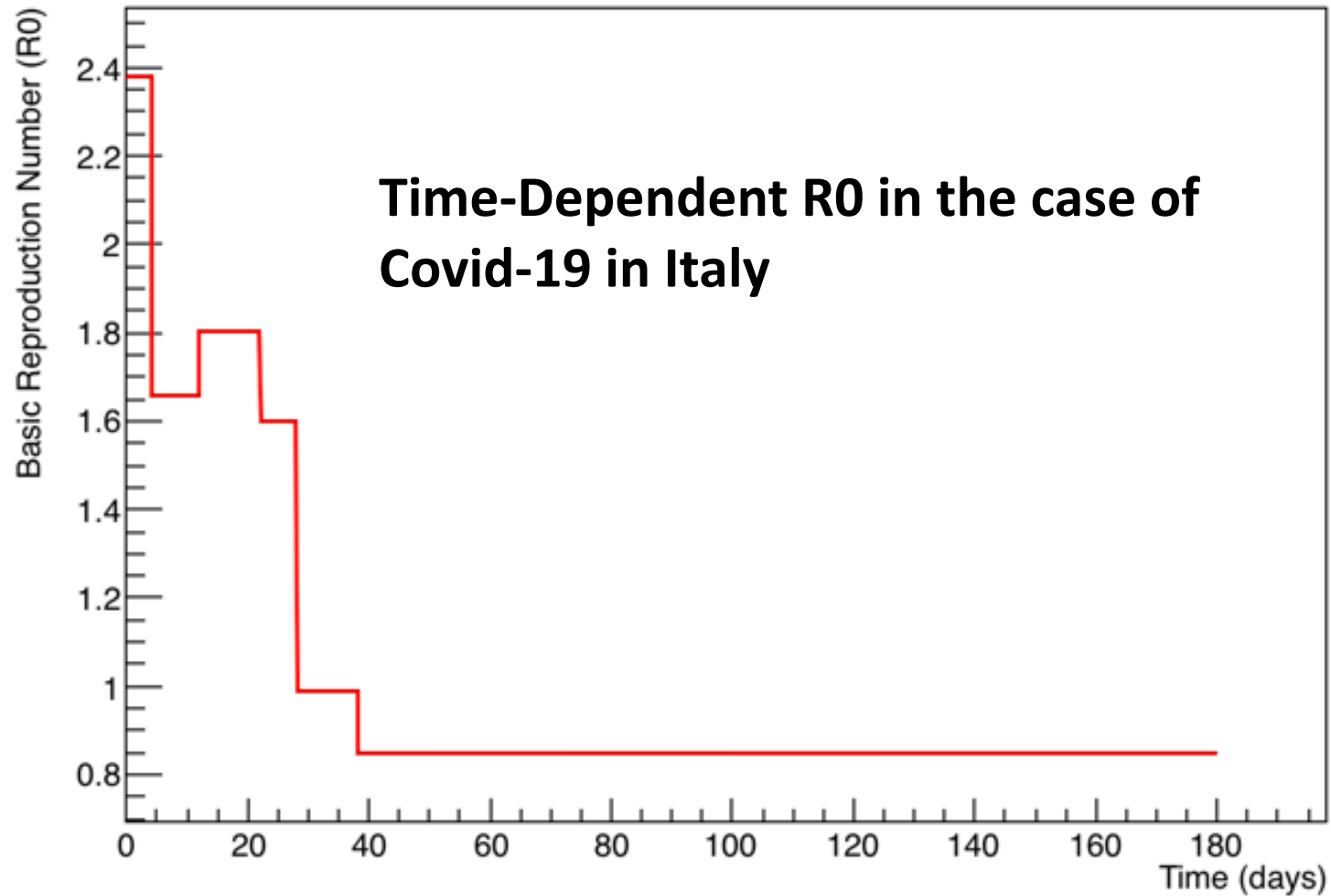
SIDARTHE – Basic Reproduction Parameter R_0

The model parameters have been updated over time to reflect the progressive introduction of increased restrictions. On day 1, the basic reproduction number was $R_0=2.38$, which resulted in a substantial outbreak. On day 4, $R_0=1.66$ as a result of the introduction of basic social distancing, awareness of the epidemic, hygiene and behavioral recommendations, and early measures by the Italian government (for example, closing schools). At day 12, asymptomatic individuals were almost no longer detected, and screening was focused on symptomatic individuals (leading to $R_0=1.80$). On day

22, a partially incomplete lockdown, of which the effectiveness was reduced by the movement of people from the north to the south of Italy when the country-wide lockdown was announced but not yet enforced, yielded $R_0=1.60$. When the national lockdown was fully operational and strictly enforced, after day 28, $R_0=0.99$, finally reaching below 1. Moreover, $R_0=0.85$ was achieved after day 38 due to a wider testing campaign that identified more mildly symptomatic infected individuals. Figure 2a shows the model evolution

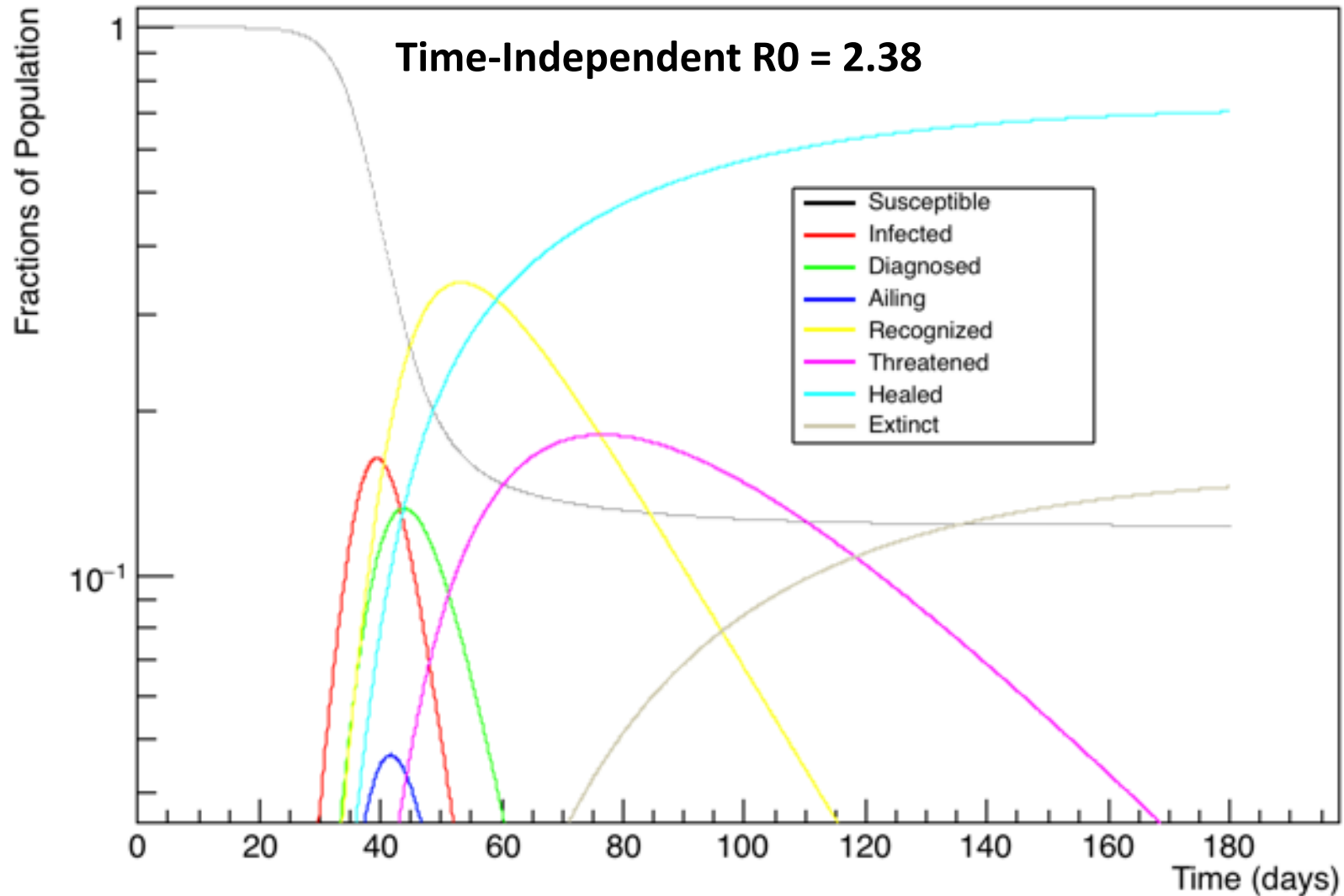
Basic Reproduction Number (R0) for Italy

SIDARTHE Model with Italy for a Time-Varied R0



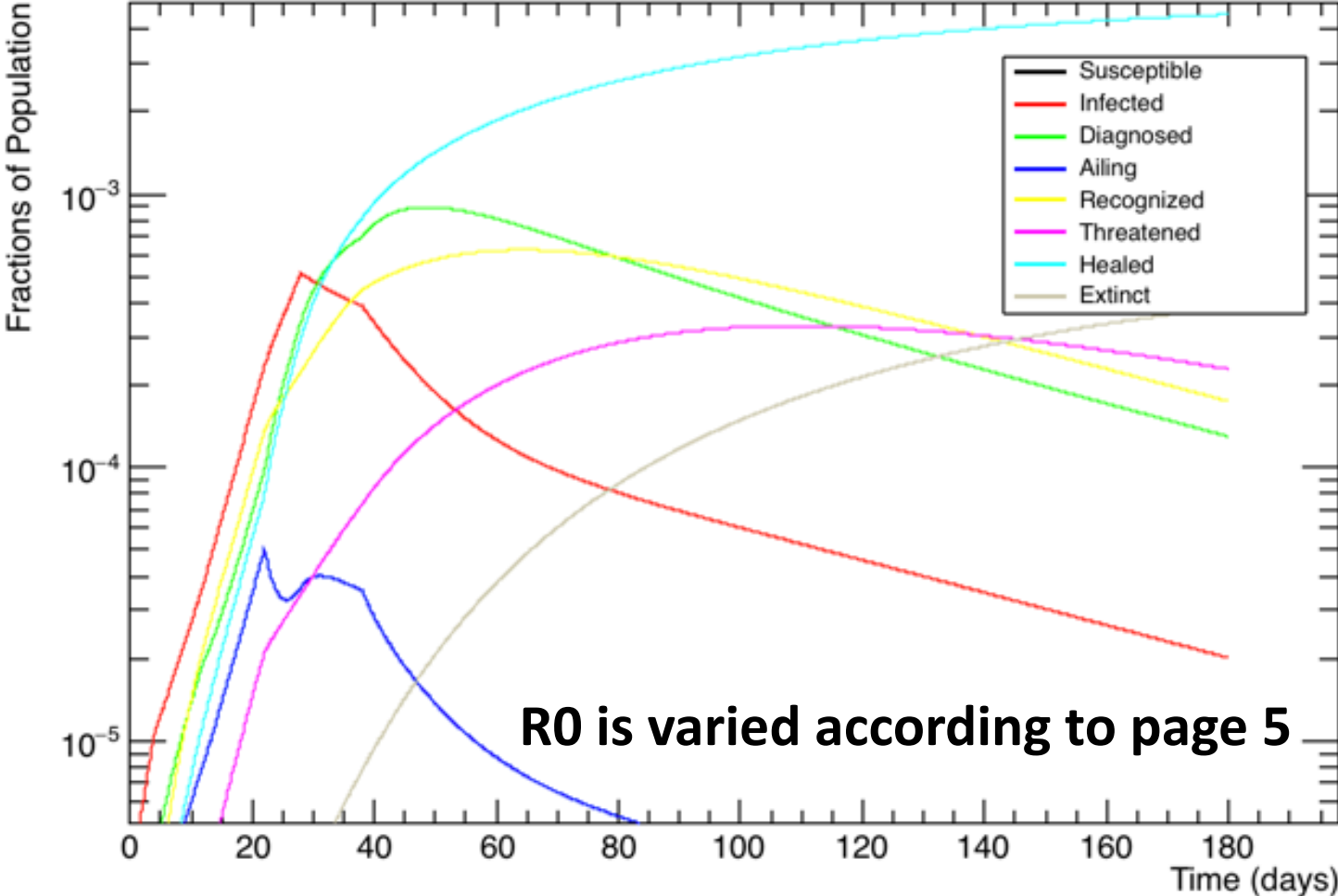
SIDARTHE Model with R0 Fixed at Day 1

SIDARTHE Model for Italy for a Fixed R0



SIDARTHE Model with Time-Dependent R0 of Page 5

SIDARTHE Model for Italy for a Time-Variied R0



Modeling data from African countries

Togo — measures taken by the government

- On 6 March, Togolese government's officials announced the first COVID-19 case, a 42-year-old Togolese woman who travelled between Germany, France, Turkey, and Benin before returning to Togo. She was being treated in isolation and her condition was stable.
- Start contact tracing, monitoring of persons under quarantine and testing of symptomatic cases.
- Surveillance at point of entry, at the borders and airports
- After an extraordinary council of ministers on 16 March, the government established the following measures: suspending flights from Italy, France, Germany, and Spain; canceling all international events for three weeks; requiring people who were recently in a high-risk country to self-isolate; closing their borders; and prohibiting events with more than 100 people effective 19 March.
- On 20 March, nine more cases were confirmed in Togo. On this day, the first case has recovered, as indicated by the Ministry of Health.

Togo continues

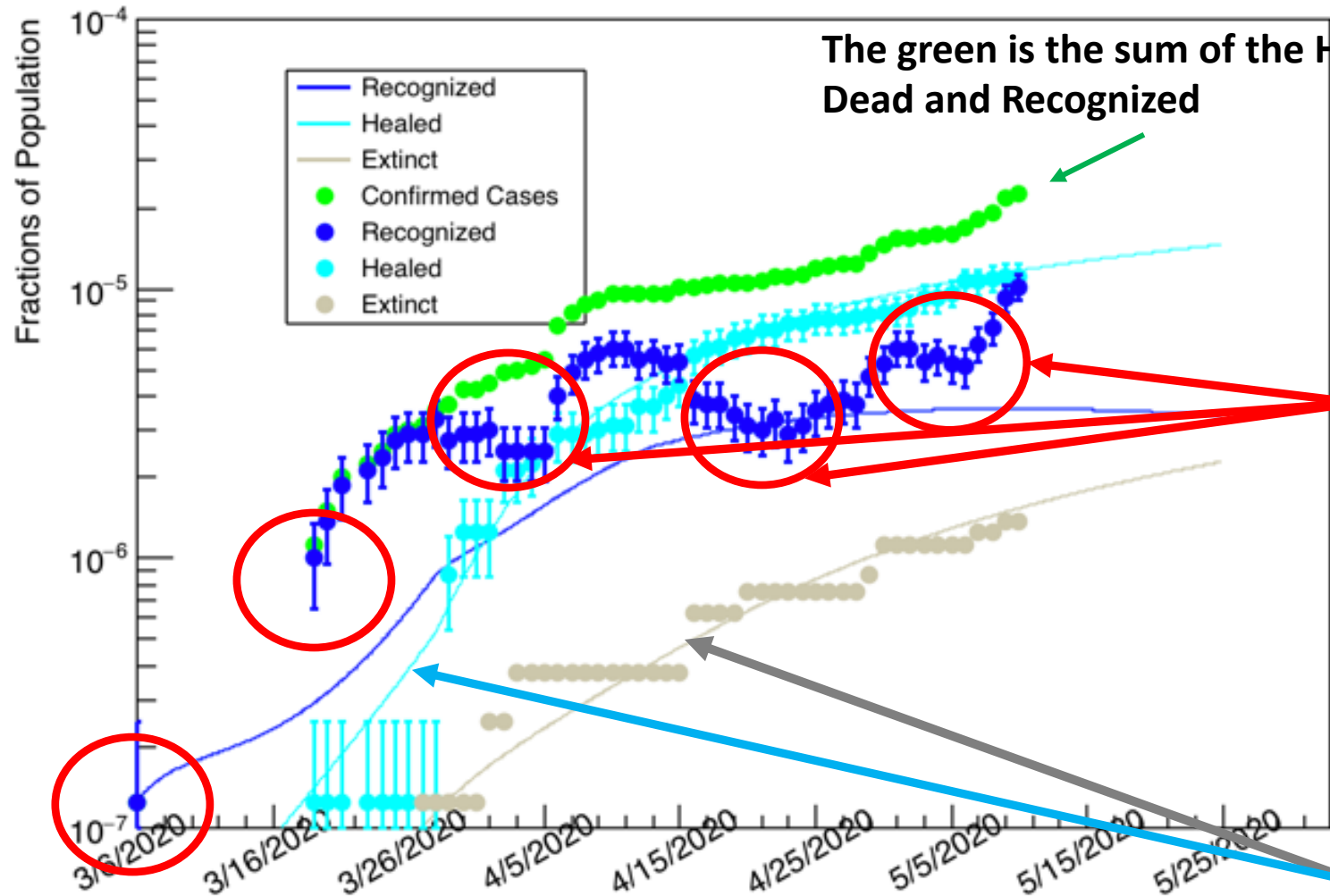
- On 21 March, seven more cases were confirmed . In an attempt to control the spread of the virus in Togo, all borders to the country were closed. The cities of Lomé, Tsévié, Kpalimé, and Sokodé have been quarantined starting on 20 March. They advised social distancing, wear of masks
- For at least two and half months schools, universities, churches, saloons, bars,... were closed. Curfew established from 9pm to 6am.
- Trucks entering the borders carrying essential commodities are tested and then proceed to their destination under surveillance. The drivers are placed under quarantine if suspect to have been in contact with a confirmed case.

Togo continues

- On 27 March, the first death occurred.
- On 07 April, start of massive tests of both symptomatic and asymptomatic cases in cities with more than 10 cases.
- Between 5 and 20 May, the number of new cases sharply increased. This is because, neighboring countries have re-opened their borders leading to an influx of Togolese nationals returning to Togo with infections.
- From 09 June, the curfew is lifted. The government made the wear of mask compulsory for the whole population, and washing hand before accessing to any public, private services or market.

Togo data with “modified” R0 and Modified initial conditions

SIDARTHE Model for Togo for a Time-Varied R0



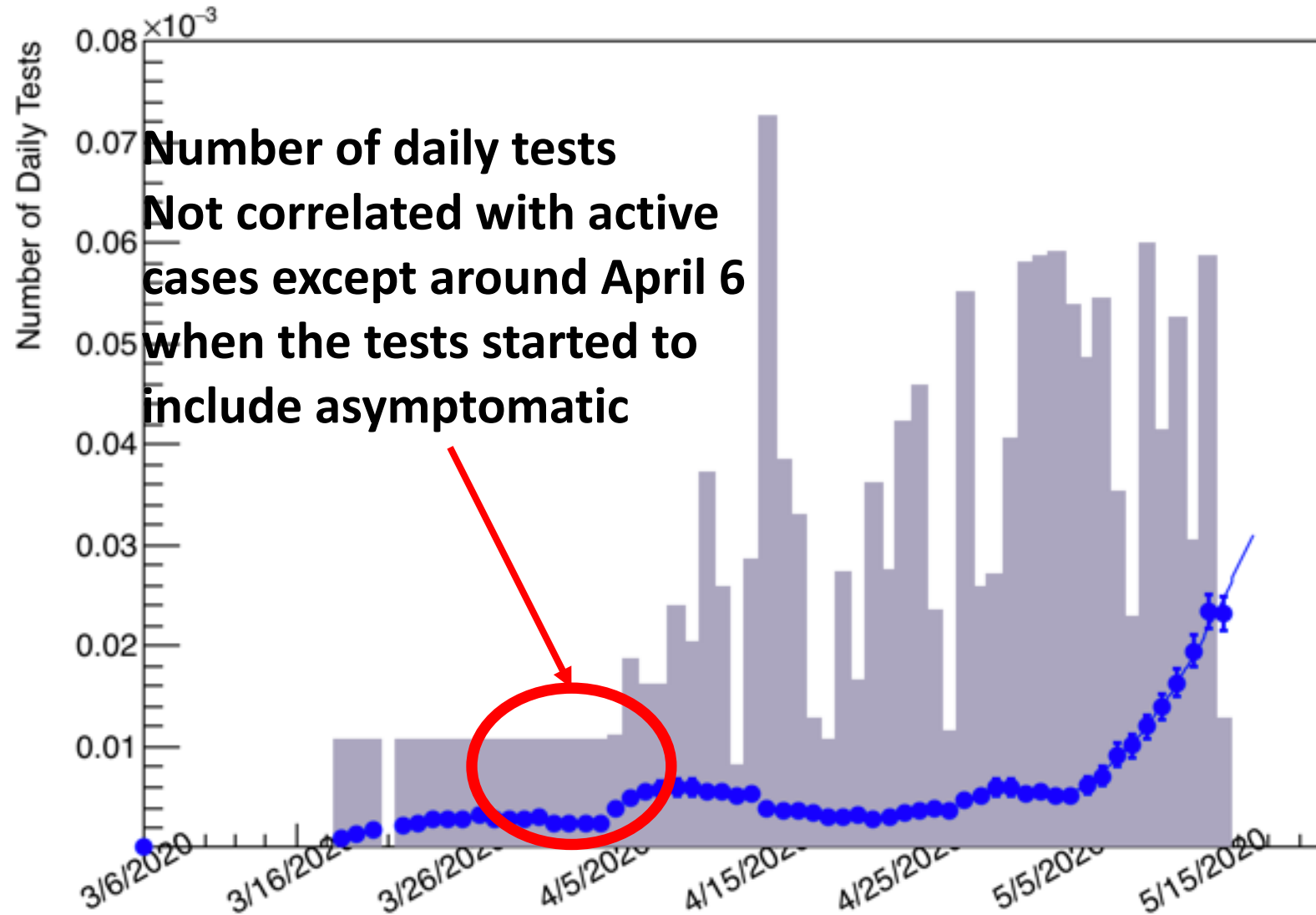
The green is the sum of the Healed, Dead and Recognized

Need to better define R0 according to this structure in the data of Togo. Need to understand what the structure corresponds to!

The Healed and Extinct seem to be somewhat well modeled.

Understanding the Covid-19 data of Togo

Number of daily COVID-19 Tests and Cases in Togo



No correlations to explain the structure in the active cases

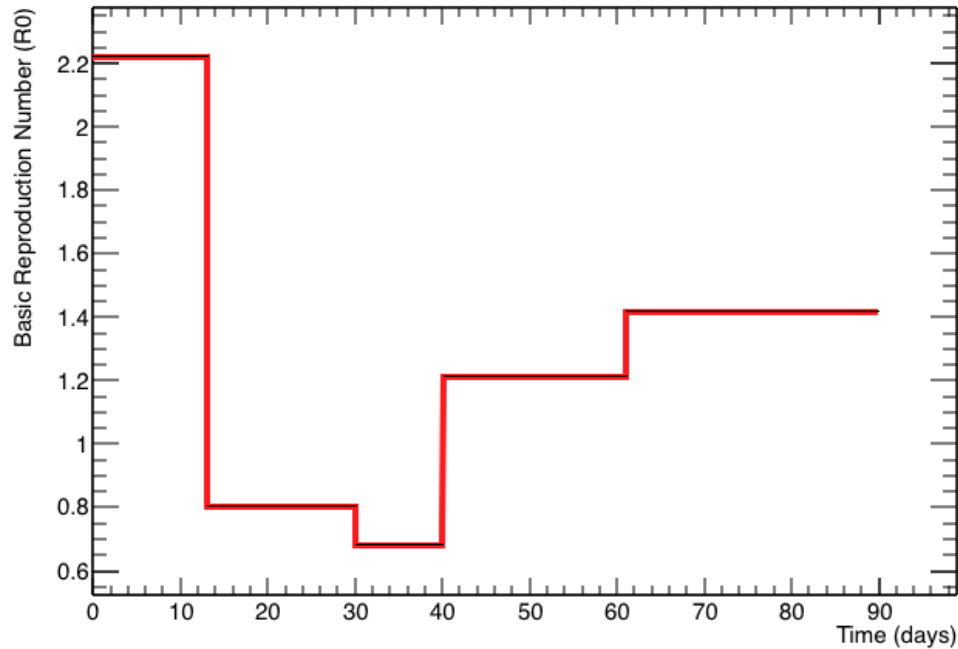
Understanding the Covid-19 data of Togo

- <https://covid19.gouv.tg/situation-au-togo/>
- Extinct \equiv Dead
- Healed \equiv Recovered
- **Before 7 April Active cases =**
Recognized +
Threatened
- **After 7 April Active cases =**
Recognized +
Threatened+
Diagnosed

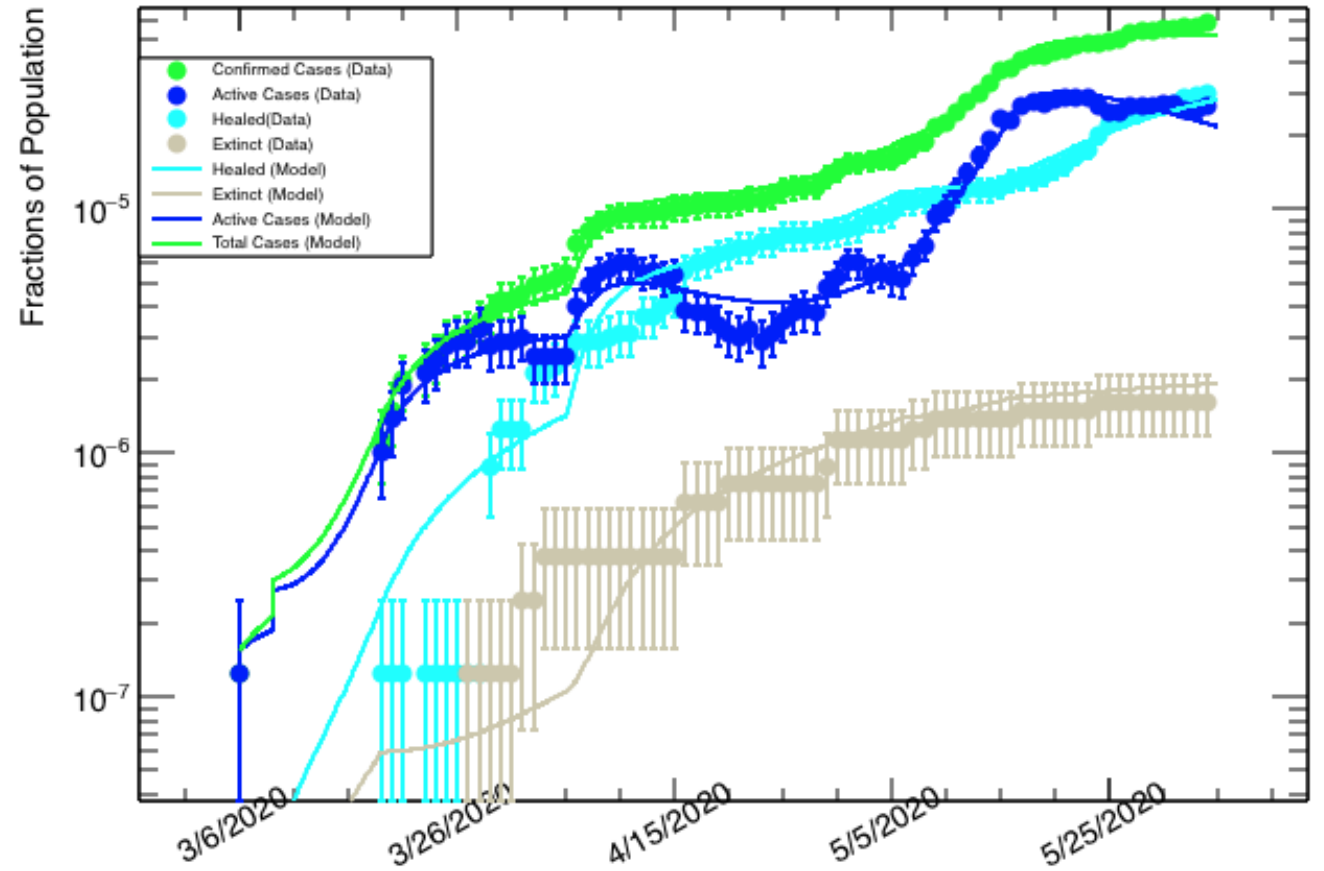
Togo

Total Population ~ 8 million
One recognized case at time zero (March 6, 2020)

Time-Dependent R_0 for COVID-19 in Togo



Modeling of Covid-19 Togo Data



Data generally well modeled. The structures in the “Active cases” corresponds to periodic rapid changes in infection rates

Zambia

- Implemented closure of schools/Universities continued screening of travelers (suspension of non-essential travel to countries with confirmed Covid-19 cases).
- “locked down” churches, saloons and sports activities are still open however bars are closed :-)
- Encouraged social distancing?

Zambia continue...

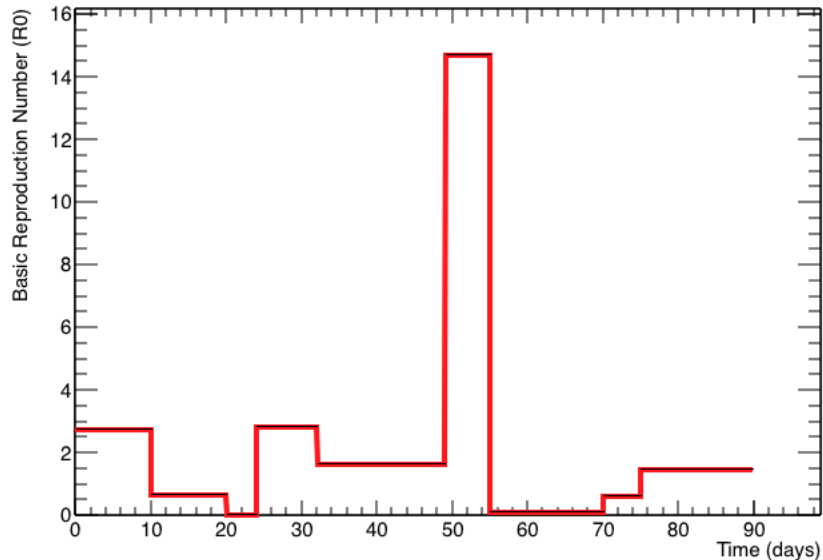
- Surveillance at community level, health facilities, point of entry (Trucks entering the borders carrying essential commodities proceed to their destination under secure escort, at which point the drivers are placed under quarantine pending test results. Other activities).
- Contact tracing and monitoring of persons under quarantine.
- Criteria for testing: individuals who meet the case definition or individuals who have had contact/been exposed to a confirmed positive case and/or are symptomatic. Testing has also been extended to all communities with confirmed cases. Testing of community alerts, suspects under quarantine, contacts of confirmed cases as well as re-testing of confirmed cases is ongoing

Zambia

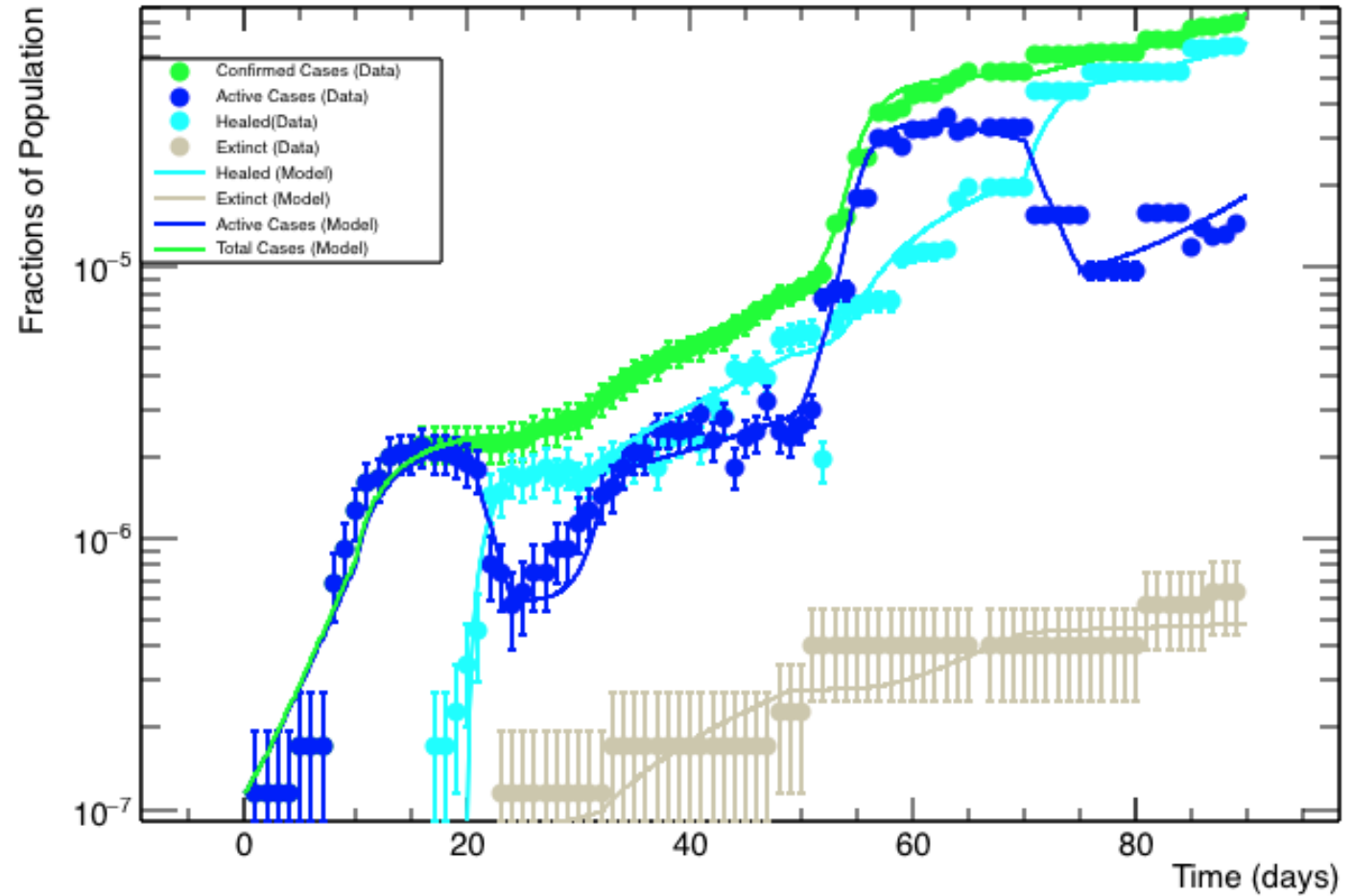
- Extinct \equiv Dead
- Healed \equiv Recovered
- **Active cases =**

**Recognized +
Threatened**

Time-Dependent R0 for COVID-19 in Zambia



Modeling of Covid-19 Zambia Data



Data well modeled by need to understand the high $R_0(t)$ at $t=50!$

Understanding Covid-19- Rwanda

- On 14th March 2020 Rwanda confirmed first case of covid-19,
- It was an Indian citizen who arrived from Mumbai, India, on 8th March 2020,
- He showed no symptoms upon arrival in Rwanda and he reported himself to a health facility on 13th March where he was tested immediately.
- By 15th March schools, places of worships, weddings were all postponed till further notice
- Testing of symptomatic cases started right away before the first case was identified probably on 9th March especially those coming from outside
- Testing of asymptomatic cases started after April 7th 2020, this was due to contact tracing.

Rwanda continue ...

- On 19th March social distancing measures were implemented to prevent the spread of the virus roughly 1meter
- Due to increase in number of cases additional safety measures were taken, on 21st March 2020, Lockdown was implemented, by closing of markets, bars, borders, airports etc.
- **Additional information**
- Contact tracing was also another measured used by Rwandan Government to collect the data, all individuals who came in contact with the infected were tested whether asymptomatic or not
- Masks are worn in all public places, markets and shops are provided with sanitizers to prevent further spread of the virus
- **NB:** Total Population of Rwanda is approximately 12 Million

Mozambique

- The first case was detected on March 22, 2020
- Waiting for the government's response regarding the testing of symptomatic and asymptomatic case
- Social distance measures were implemented on March 23, 2020
- Since April 1st until now we are in a state of emergency.
- In our country we did not go to the lockdown yet
- Now we have 737 infected cases, 550 active cases, 181 recovered cases and 5 dead.
- Now our government together with the direction of schools and universities are analyzing how and when we will return to classes and it is believed that it will be soon.

Conclusions

- So far we've achieved a reasonable modeling of the data of Togo and Zambia. We will continue with Rwanda, Mozambique, Benin and Kenya.
- Then, we will report our results to the respective government and publish a paper
- Afterward, we will go into the modeling, from first principle, with Monte Carlo simulation and Machine Learning analysis to study the factors that are driving the evolution of the cases in African countries