

SARS-CoV2 Simulations for India including Vaccinations

Computation Decision Science Laboratory*,
Illinois Institute of Technology
<https://sars-covid-tracker-india.herokuapp.com>
e-mail:kapoor@iit.edu

July, 26th 2021

1 Current Projections after lockdown - comparing Vaccination rates

We extend our model to consider the release from lockdown in India in June, 2021. The analysis is based on an initial growth in population that were part of transmission dynamic in the early part of 2021 to provide for rise in cases following the potential increase in the susceptible population. A second release of population was also estimated after the release of lockdown in June. The current projections below are based on data until July 16th, 2021. We will quantify the second release with respect to the susceptible population that was computed during February-March 2021 when restrictions were removed in January. Vaccination rates are integrated in these projections. The vaccination rate is applied uniformly across Indian states and applied to the susceptible population that is present in our compartment model (based on the SEIR model) which has asymptomatic, hospitalized and death compartments and incorporates lockdown impacts for predictive modeling of virus spread in Indian states and an India aggregate model from individual states model. We consider two types of additional release from lockdown. Additional removal lockdown policies starts at 8/01/2021 and the population returns to the status in February/March in 30, 45 and 60 days. We compare the number of cases and deaths under the current vaccination rate and in the case when the vaccination rate is doubled.

Parameters

- Current Vaccination rates: 3.0M (30 Lakhs)/day or approximately 0.225%/day.
- Projected vaccination rate: 5.0M (50 Lakhs)/day or approximately 0.375%/day from August 1st, 2021.
- Additional lockdown removal date: Aug. 1st, 2021 and Lockdown release rate:
 - (a) 100% over 30 days
 - (b) 100% over 45 days
 - (c) 100% over 60 days

Discussion

Our simulation shows that reducing the rate of release from lockdown will substantially reduce the number of cases and deaths: For the current vaccination rates are:

*Laboratory partially supported by NSF, USA

- Reduction of 64.04% in total cases and 62.46% in total deaths in the case of release over 45 days instead of 30 days. The reduction in total cases is 10.35M, and deaths is 129,767. The anticipated number of cases are 16.5M and 5.8M while deaths are 207,744 and 77,977 for the 30 and 45 day release.
- In the case of a period of release (60 days) the improvements in cases and deaths are 80.69% and 76.85, respectively, as compared to a 30 day release. The reduction in total cases is 13.04M and deaths are reduced by 159,652. The anticipated number of cases are 3.12M and deaths are 48,091 for the release over 60 days.

This indicates benefits of a slow release of population over 60 days to reduce likelihood of a high third peak, along with possible increase in vaccination rates to 5M/day. Other steps available are stricter contact tracing and testing. These would help substantially.

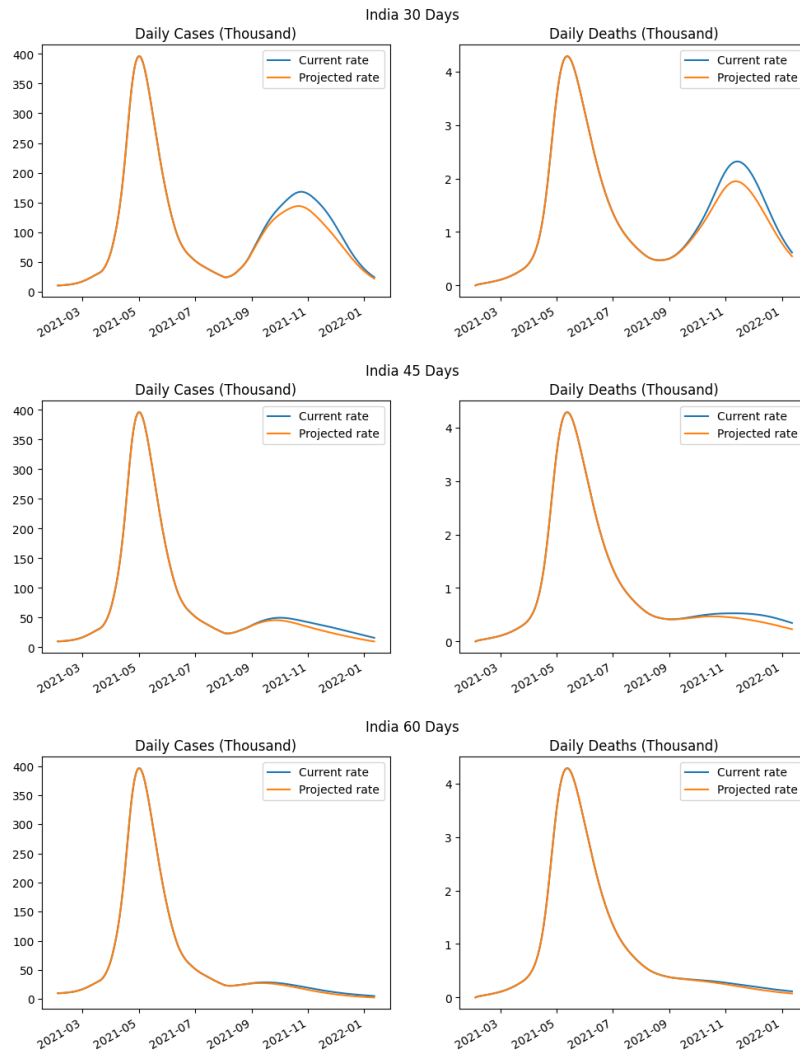


Figure 1: Comparison of three scenarios: releasing population from lockdown over 30, 45 and 60 days

state	ratio	state	ratio
India	12.97%		
Andaman and Nicobar	85.88%	Lakshdweep	0.00%
Andhra Pradesh	12.95%	Madhya Pradesh	0.00%
Arunachal Pradesh	72.34%	Maharashtra	27.91%
Assam	30.81%	Manipur	90.91%
Bihar	0.00%	Meghalaya	58.68%
Chandigarh	0.00%	Mizoram	81.42%
Chhattisgarh	0.00%	Nagaland	90.91%
Daman and Diu	0.00%	Odisha	0.00%
Delhi	0.00%	Puducherry	0.00%
Goa	34.43%	Punjab	0.00%
Gujarat	0.00%	Rajasthan	0.00%
Haryana	0.00%	Sikkim	0.00%
Himachal Pradesh	0.00%	Tamil Nadu	0.00%
Jammu and Kashmir	0.00%	Telangana	0.00%
Jharkhand	0.00%	Tripura	56.31%
Karnataka	15.90%	Uttar Pradesh	0.00%
Kerala	41.07%	Uttarakhand	0.00%
Ladakh	0.00%	West Bengal	0.00%

Table 1: Release ratios: Population release in second lockdown relaxation as a fraction of release in lockdown relaxation in February and March.

2 Current Stagnation in case loads

Using our model we estimated the population that was released as a result of removal of lockdown in June 2021 and that resulted in increase or stagnation in the number of cases. This is expressed as a fraction of the population released into the susceptible set during the removal of lockdown in January. Table 1 shows the release in various states corresponding to possible non-compliance with mask mandates that impact viral transmission, leading to a much slower reduction in total number of cases or increase in some states. The overall release fraction is roughly 13% which, when considering the speed of vaccination, results in stagnation or very slow decreases in number of cases.

3 Impact of Policies: Masks and social distancing

There is a positive correlation between decrease in mask usage and rise in mobility with respect to rise of cases. We estimated the proportion of population that were added to the susceptible pool during March and April and correlated it to mobility and mask usage via a constrained log linear model (details in the full version) in the months of February and March. The correlation is reasonably high establishing the importance of wearing masks and restricting mobility. While in some places lack of mask adherence played a strong role, in others mobility played a strong role (Table 2). Overall masks showed a significant impact in 15 out of 27 states.

For the overall behavior in India consider the mask and social distancing (mobility) measures. As illustrated in the figure (Fig. 2) there has been a reduction in usage of masks by at least 7% points and increase in mobility causing addition to the susceptible population (our current estimate is 13%). Since the release is time dependent, there may be further impact of this reduction in usage of masks and increased mobility.

state	mask coefficient	social distancing coefficient	correlation
Andhra Pradesh	9.00	0.00	0.9052
Arunachal Pradesh	3.27	1.89	0.9730
Assam	6.04	0.63	0.9825
Bihar	26.16	0.94	0.9540
Chhattisgarh	0.00	5.53	0.6661
Delhi	0.00	14.91	0.7469
Goa	0.00	2.86	0.7212
Gujarat	80.07	2.82	0.9372
Haryana	0.00	2.26	0.6462
Himachal Pradesh	16.70	1.14	0.8911
Jharkhand	0.00	5.06	0.8972
Karnataka	0.00	6.62	0.9423
Kerala	0.00	3.67	0.9309
Madhya Pradesh	20.27	0.00	0.7638
Maharashtra	8.80	3.28	0.8700
Manipur	1.96	1.93	0.9843
Meghalaya	3.22	0.00	0.9671
Nagaland	0.00	1.28	0.9504
Odisha	12.42	1.92	0.9187
Punjab	0.00	5.01	0.6348
Rajasthan	12.23	0.00	0.6078
Tamil Nadu	51.53	21.54	0.8735
Telangana	18.25	3.24	0.8340
Tripura	0.00	1.18	0.6968
Uttar Pradesh	0.00	48.78	0.6776
Uttarakhand	0.12	0.95	0.9507
West Bengal	15.93	6.21	0.8434

Table 2: Correlation between Cases and NPIs

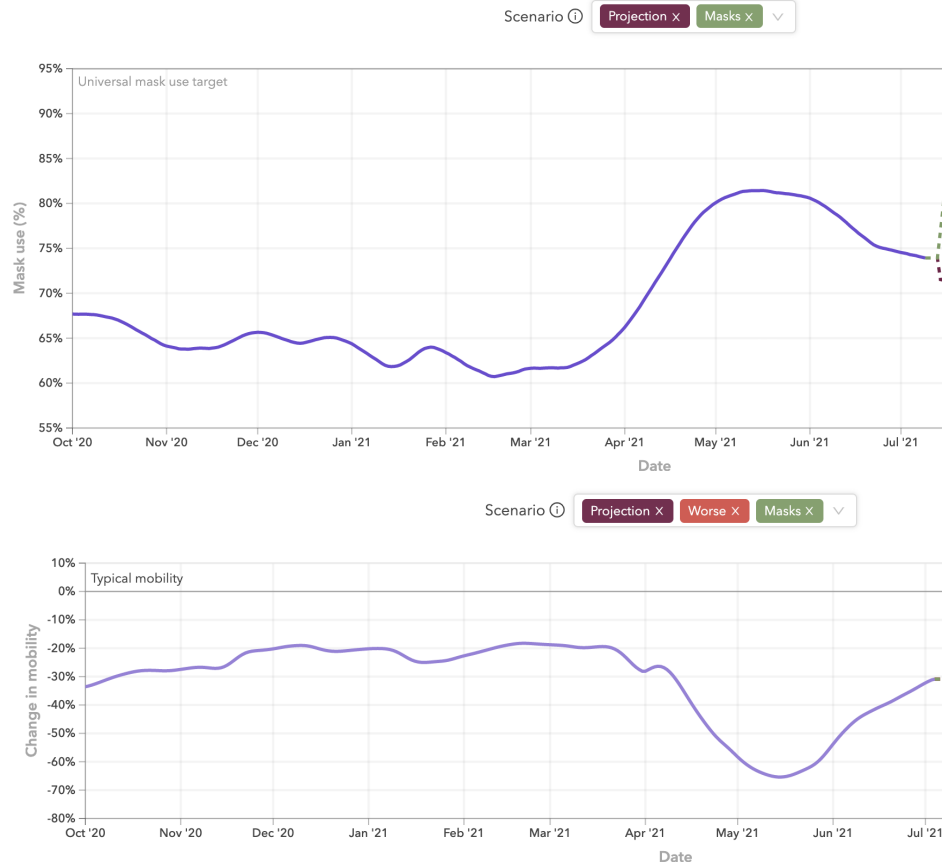


Figure 2: Mask Usage and mobility in India (source IHME)

4 Appendix-1: Statewide Analysis with increased vaccination rates

We present the improvements state-wise in the three scenarios, i.e. the release of population over 30, 45 and 60 days starting on August 1st, 2021. The figures and tables illustrating the benefits follow:

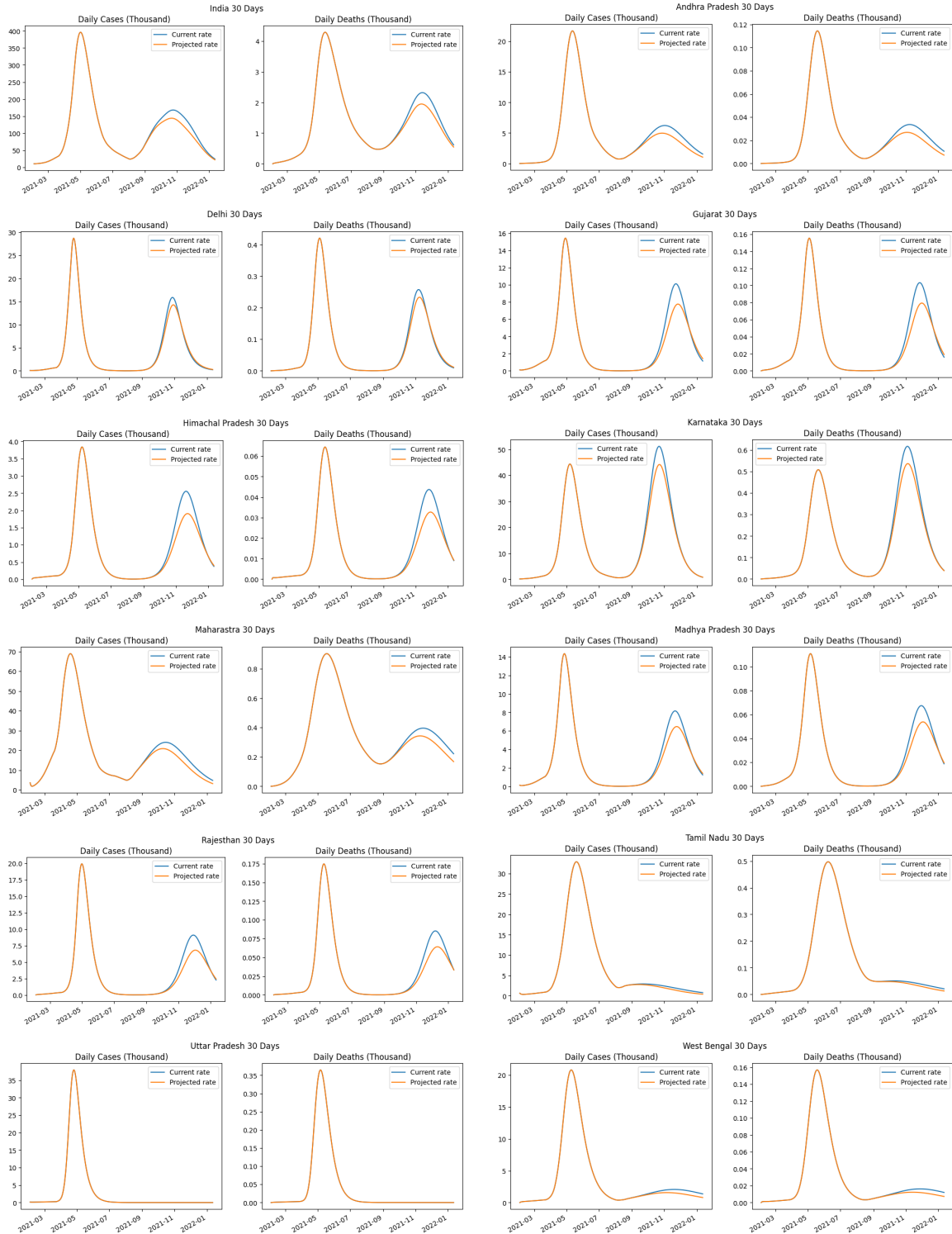


Figure 3: Projection with population release over 30 days

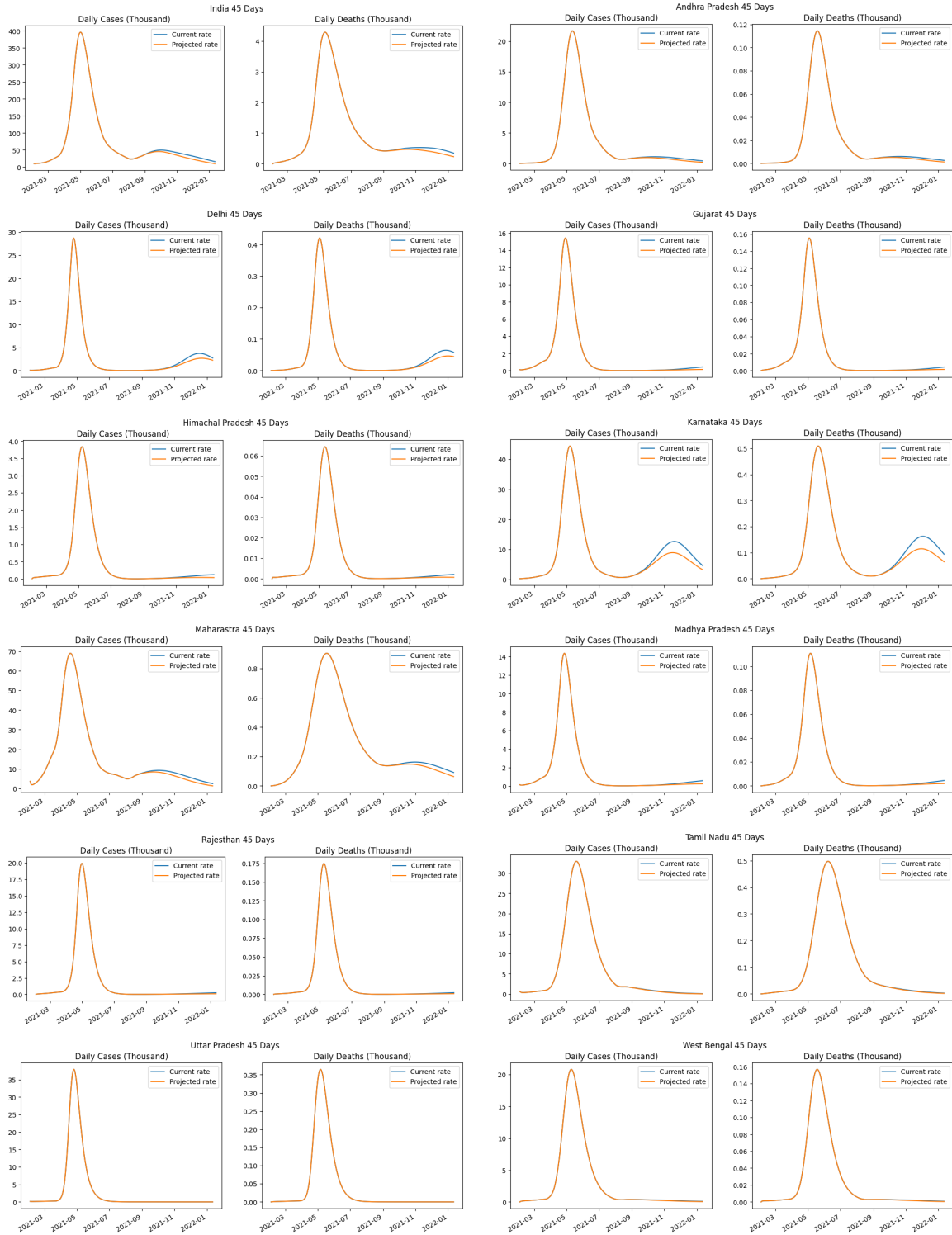


Figure 4: Projection with population release over 45 days

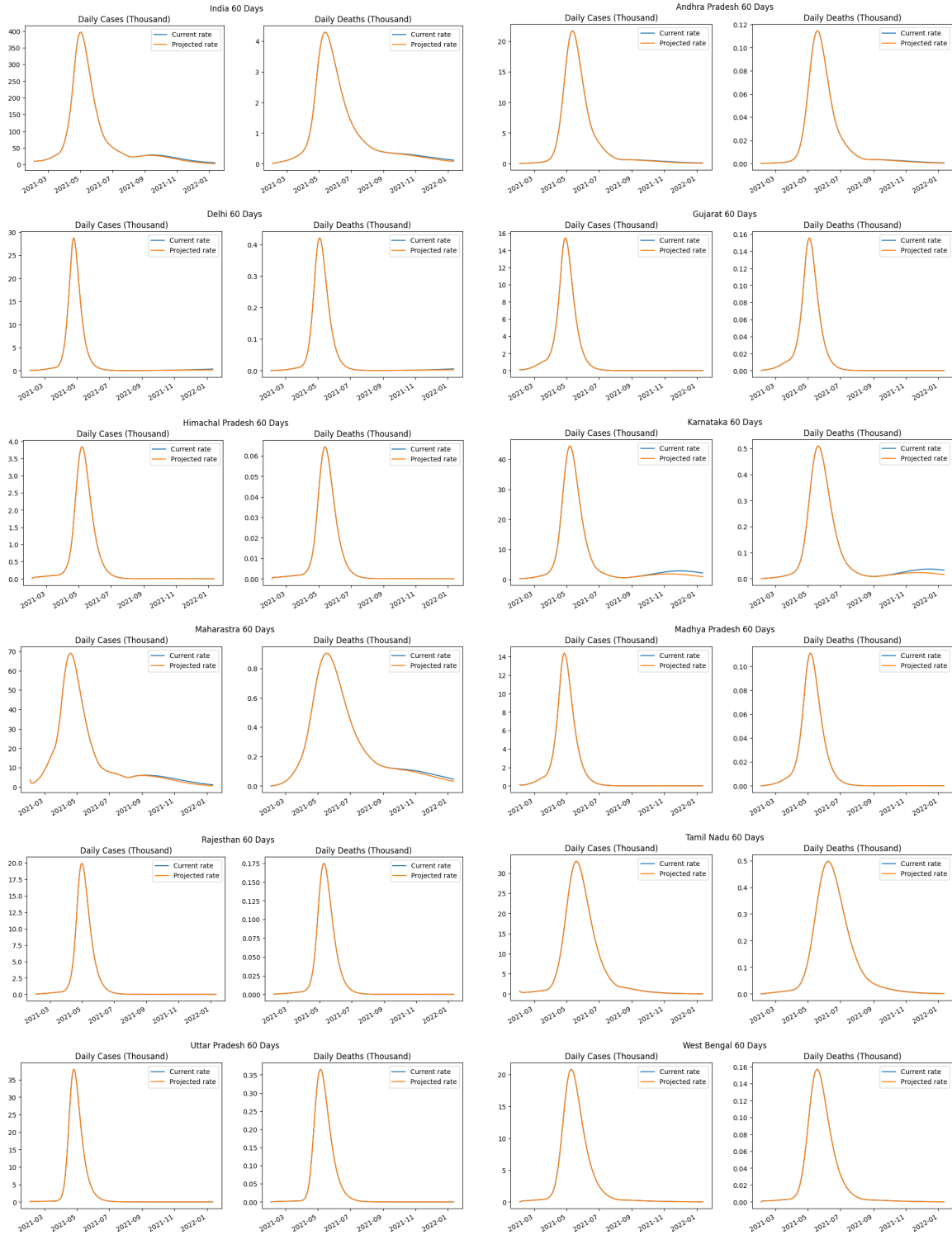


Figure 5: Projection with population release over 60 days

state	Improvement in Cases		Improvement in Deaths	
	45 Days	60 Days	45 Days	60 Days
India	64.04%	80.69%	62.46%	76.85%
Andaman and Nicobar	22.61%	32.89%	20.56%	29.87%
Andhra Pradesh	75.92%	89.24%	75.01%	88.01%
Arunachal Pradesh	18.43%	27.13%	17.26%	25.39%
Assam	32.25%	45.67%	30.87%	43.71%
Bihar	74.00%	82.12%	0.41%	0.47%
Chandigarh	92.69%	99.49%	93.83%	99.23%
Chhattisgarh	95.34%	99.64%	95.71%	99.62%
Daman and Diu	63.20%	78.64%	62.36%	77.64%
Delhi	66.72%	97.23%	71.20%	97.66%
Goa	40.81%	62.33%	40.66%	62.21%
Gujarat	96.27%	99.82%	96.59%	99.81%
Haryana	98.00%	99.88%	98.22%	99.81%
Himachal Pradesh	94.56%	99.49%	94.89%	99.44%
Jammu and Kashmir	85.78%	97.45%	86.36%	97.25%
Jharkhand	98.80%	99.88%	98.82%	99.86%
Karnataka	62.15%	89.25%	64.54%	89.67%
Kerala	43.27%	62.94%	40.95%	59.14%
Ladakh	82.31%	93.19%	75.13%	84.83%
Lakshdweep	51.33%	67.18%	45.17%	59.13%
Madhya Pradesh	93.66%	99.51%	94.45%	99.44%
Maharashtra	55.27%	72.25%	47.39%	61.38%
Manipur	16.68%	24.50%	15.84%	23.27%
Meghalaya	40.67%	58.98%	39.60%	57.42%
Mizoram	18.15%	26.64%	8.74%	12.81%
Nagaland	27.44%	40.03%	25.96%	37.86%
Odisha	53.12%	70.83%	45.26%	59.99%
Puducherry	87.53%	97.98%	88.05%	97.79%
Punjab	85.73%	98.46%	87.24%	98.32%
Rajasthan	97.39%	99.80%	97.60%	99.75%
Sikkim	34.98%	48.35%	33.70%	46.59%
Tamil Nadu	60.59%	72.95%	44.11%	53.51%
Telangana	59.18%	78.32%	59.01%	77.87%
Tripura	36.24%	52.75%	33.67%	48.96%
Uttar Pradesh	77.71%	85.27%	58.30%	64.25%
Uttarakhand	96.74%	99.75%	97.01%	99.69%
West Bengal	81.58%	90.65%	79.07%	88.11%

Table 3: Improvement over 30-Day Release

5 Appendix-2: Validating model using data from UK

We used data from UK from December 2020 till July 2021 to fit our model that included vaccination rate. The vaccination rate was an average of 0.5% per day. A delay of 12 weeks between first and second dose vaccinations was used. Our results are illustrated in figure 7. In UK lockdown was partially removed in April and May, when restrictions on bars restaurants were removed, though small bubbles were mandated. Listed below are lockdown removals in UK:

- April 12th: COVID rules are eased in all of the Home Nations, with changes including the reopening of non-essential retail in England and Wales, the end of the "stay at home" order in Northern Ireland, and the return of all school pupils in Northern Ireland and Scotland. Shops, hairdressers, gyms and outdoor hospitality could reopen on 12 April in England under plans set out by the Prime Minister.
- From 17 May, two households might be allowed to mix in homes, while the rule of six could apply in places like pubs.

Our fitting results provide estimate for the population that has been released from under lockdown. This estimate is almost 100% of the susceptible population that was present during December 2020. The reduction in daily new cases can be attributed to a high rate of vaccinations. The data shows substantially increased mobility and lower social distancing measures (as measured via mask usage). This is illustrated in figure 6 which shows the reduction in mask usage to 50% and substantially increased mobility.

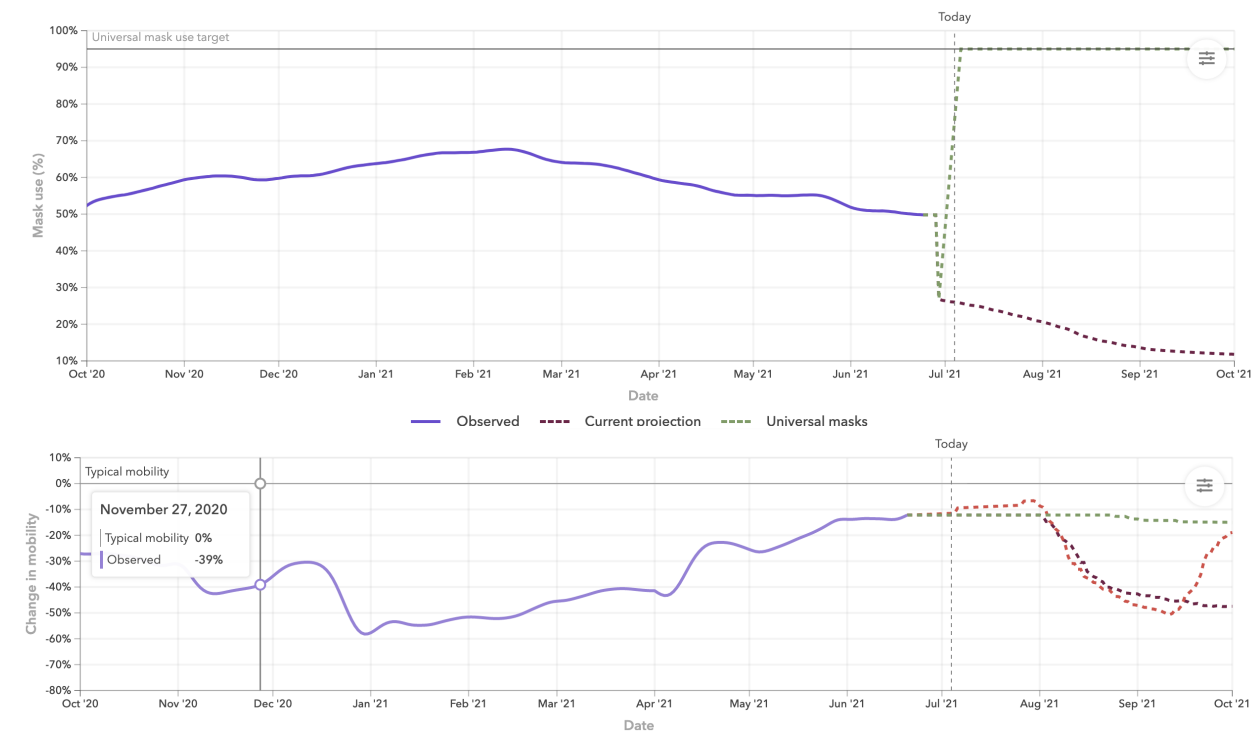


Figure 6: Mask Usage and mobility in UK (source IHME)

Our error analysis is illustrated in the tables 4 and 5. The fitting was more accurate for cumulative case projections. The daily case numbers were substantially smaller and showed large daily variations.

UK

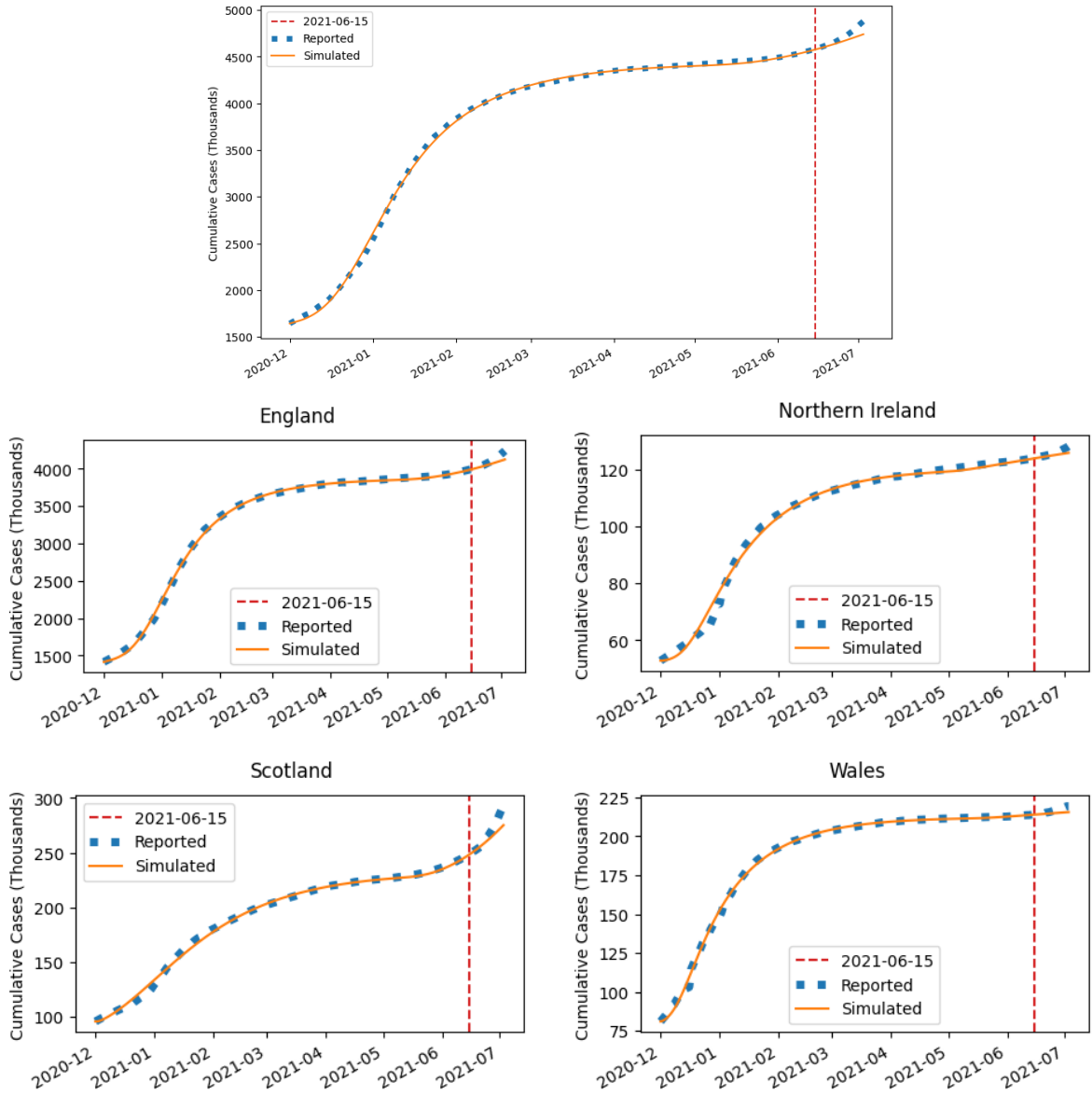


Figure 7: Fitting and Projections in UK(15th June, 2021)

Fitting Date	1 week	2 weeks
6/8/21	27.40%	34.61%
6/15/21	11.80%	23.51%
6/22/21	20.90%	

Table 4: Error in daily new case projections in UK

Fitting Date	1 week	2 weeks
6/8/21	0.21%	0.43%
6/15/21	0.17%	0.39%
6/22/21	0.33%	

Table 5: Error in cumulative case projections in UK