

# **SARS-CoV2 Projections for India including Vaccinations**

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## **1 Current Projections with Vaccination rates**

We consider the ongoing Sars-Cov2 crisis and present case results from our model that considers the impact of relaxation of rules of lockdown in India starting in June, 2021. The analysis is based on the initial growth in population that were part of transmission dynamics in the early part of 2021 and that provides a baseline for rise in cases. After lockdown removal in June, a release of population that adopts the behaviour of the baseline is estimated. The current projections below are based on data until August 14th 2021. Using the baseline scenario We will quantify the second release with respect to the susceptible population estimation that was computed during February-March 2021 when restrictions were removed in January. Vaccination rates are integrated in these projections. We assume that the vaccination rate is applied uniformly across Indian states 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 8/30/2021 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**

- Baseline established during February to March, 2021.
- Average Vaccination rates: 3.0M (30 Lakhs)/day or approximately 0.225%/day over the last 100 days. This average will increase over time.
- Additional lockdown removal date: August 30th, 2021 and Lockdown release rate:
  - (a) 100% of baseline over 30 days
  - (b) 100% of baseline over 45 days
  - (c) 100% of baseline over 60 days

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## Discussion

Our modeling shows a substantial change from July 2021. The stagnation of cases and lack of decrease in infections during July 2021 resulted from a release in susceptible population in some states. 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 33%** which, when considering the speed of vaccination, results in stagnation or very slow increase in number of cases. This impacts the growth of infections in the next few months.

We consider two scenarios:

**Scenario 1 (pessimistic scenario):** The first scenario is when the next release is estimated from only the established baseline scenario. This guides the possible susceptible population in the next few months. The population that has already become part of the susceptible pool after the relaxation from lockdown is ignored. This method has been used to create the projections in previous analysis and accounts for the total population of the state. This model indicates a substantial rise in infections when rules regarding lockdown are relaxed.

Our results project very high case loads during October and November months. A cautious approach is necessary in the future months. Reducing the rate of release from lockdown will substantially reduce the number of cases and deaths: For the current vaccination rates these reduction are substantial.

- Reduction of 48.63% in total cases and 44.85% in total deaths in the case of release over 45 days instead of 30 days. The reduction in total cases is 11M, and deaths is 133,487. The anticipated number of cases after release on August 30th, 2021 are 22.66M and 11.64M while deaths are 297,617 and 164,130 for the 30 and 45 day release.
- In the case of a period of release (60 days) the improvements in cases and deaths are 68.29% and 62.89, respectively, as compared to a 30 day release. The reduction in total cases is 15.48M and deaths are reduced by 187,183. The anticipated number of cases are 7.18M and deaths are 110,434 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. Increase in vaccination rates will help further. Other steps available are **local lockdowns, extensive testing and stricter contact tracing**. These would help substantially.

**Scenario 2 (optimistic scenario):** In this scenario we will assume that the susceptible that are added after relaxation of lockdown but before the 14th August, were already exhibiting the baseline behaviour and are discounted from future release of population into the susceptible pool. This is an optimistic scenario.

The two scenarios are illustrated in the figures below (Figure 1). The improvements in gradual removal of lockdown rules are substantial.

## 2 States with high estimates.

Our model as applied to the states indicated a number of high risk states. While these states are not immediately showing large cases, there are indications of growth in the number of infections. These include Andhra Pradesh, Delhi, Gujarat, Himachal Pradesh, Karnataka, Maharashtra, Kerala, Punjab, Rajasthan, Uttarakhand, Haryana, North Eastern states like Nagaland.

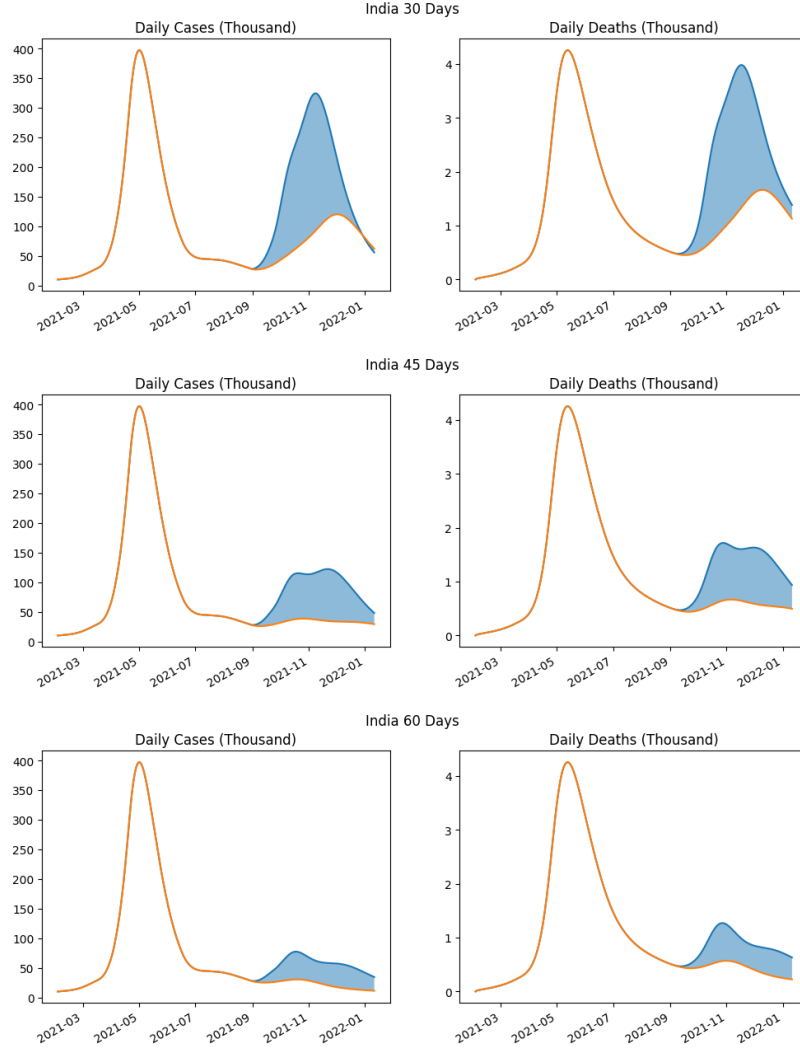


Figure 1: Comparison of three scenarios: releasing population from lockdown over 30, 45 and 60 days. Blue indicates the worst case behavior (Scenario 1) and Orange indicate the optimistic Scenario 2. The shaded blue curve indicates intermediate scenarios.

### 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

state	ratio	state	ratio
<b>India</b>	<b>32.72%</b>		
Andaman and Nicobar	0.00%	Lakshdweep	0.00%
Andhra Pradesh	34.01%	Madhya Pradesh	7.68%
Arunachal Pradesh	43.51%	Maharastra	37.44%
Assam	20.97%	Manipur	52.13%
Bihar	28.78%	Meghalaya	65.09%
Chandigarh	187.53%	Mizoram	90.91%
Chhattisgarh	23.73%	Nagaland	57.84%
Daman and Diu	2.06%	Odisha	15.94%
Delhi	27.62%	Puducherry	36.30%
Goa	36.90%	Punjab	95.37%
Gujarat	29.68%	Rajasthan	55.39%
Haryana	33.86%	Sikkim	25.60%
Himachal Pradesh	73.82%	Tamil Nadu	0.00%
Jammu and Kashmir	39.36%	Telangana	21.89%
Jharkhand	30.49%	Tripura	40.11%
Karnataka	40.69%	Uttar Pradesh	2.60%
Kerala	71.80%	Uttarakhand	35.35%
Ladakh	0.00%	West Bengal	36.35%

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

figure (Fig. 2) there has been a reduction in usage of masks by at least 11% points and increase in mobility causing addition to the susceptible population (Note that our current estimate is 33%). 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	lag(days)	correlation
Andhra Pradesh	39.98	21.86	61	0.9452
Arunachal Pradesh	2.30	12.58	28	0.9920
Assam	4.93	0.00	25	0.9879
Bihar	0.00	19.02	0	0.9588
Chhattisgarh	0.00	10.57	2	0.9580
Delhi	0.00	5.96	0	0.9425
Goa	0.01	5.83	0	0.9832
Gujarat	14.06	28.09	23	0.9927
Haryana	12.67	21.96	6	0.9624
Himachal Pradesh	20.40	0.00	64	0.9241
Jharkhand	7.15	51.29	0	0.8721
Karnataka	1.87	13.22	0	0.9946
Kerala	0.00	11.83	43	0.2679
Madhya Pradesh	0.00	20.01	10	0.9650
Maharashtra	0.00	2.85	0	0.9881
Manipur	8.95	0.00	51	0.9870
Meghalaya	8.99	4.93	44	0.9987
Nagaland	4.03	0.47	60	0.9980
Odisha	29.85	42.52	41	0.9700
Punjab	0.00	27.79	23	0.9793
Rajasthan	21.26	0.00	41	0.9627
Tamil Nadu	0.00	100.84	9	0.9664
Telangana	23.48	0.00	41	0.9874
Tripura	14.72	12.94	47	0.9905
Uttar Pradesh	0.00	17.78	3	0.9206
Uttarakhand	4.40	98.00	2	0.7727
West Bengal	0.00	21.62	6	0.9533

Table 2: Correlation between Cases and NPIs

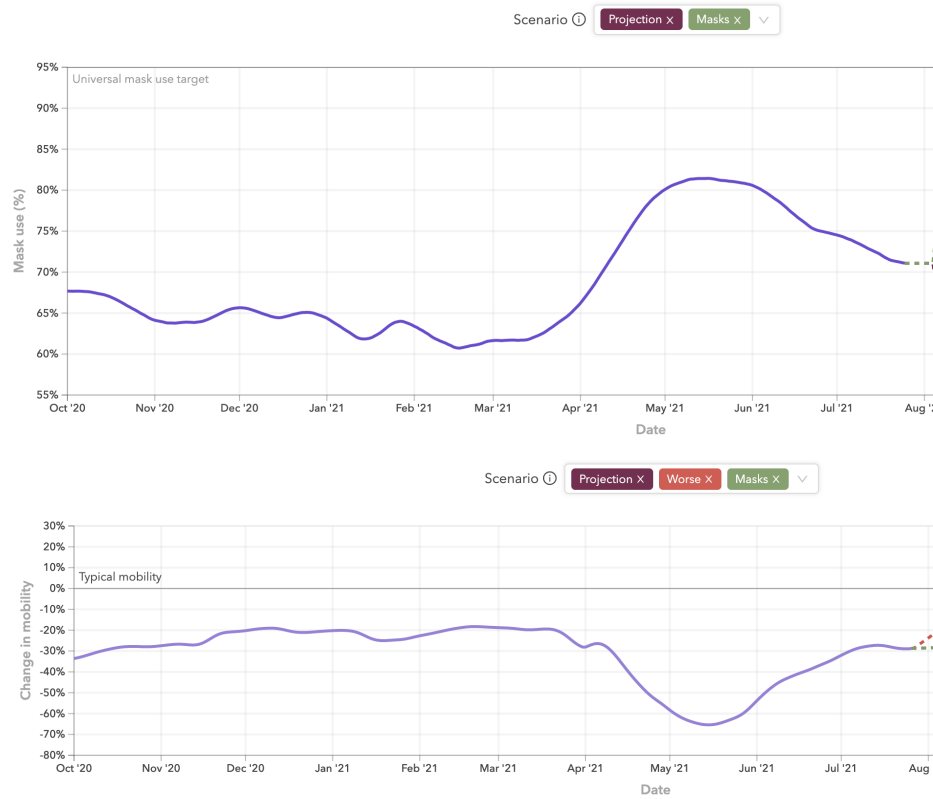


Figure 2: Mask Usage and mobility in India (source IHME). Mask usage has dropped by 11% points while social distancing has been almost fully reversed to pre-lockdown state.

## 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 30th, 2021. The figures and tables illustrating the benefits follow:

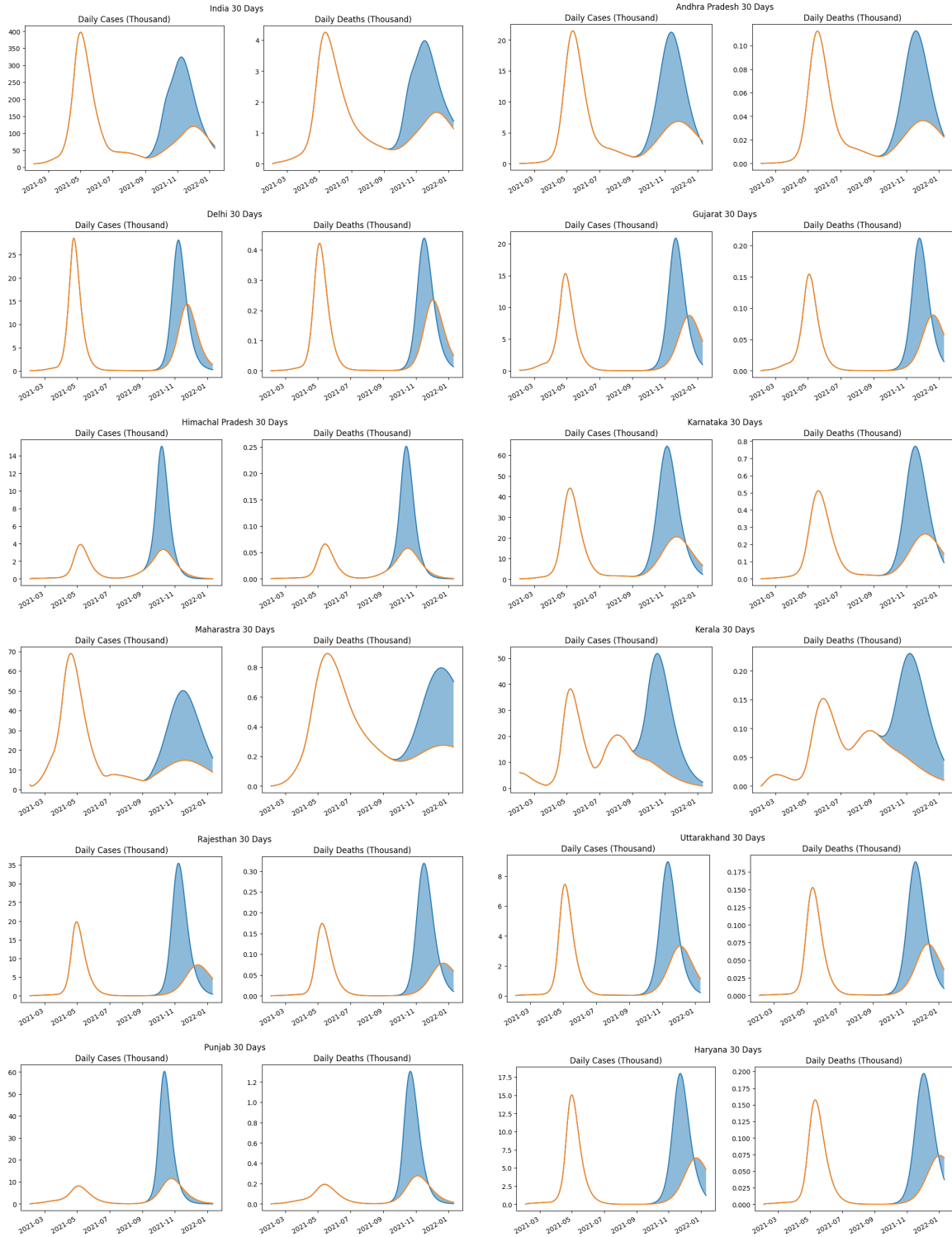


Figure 3: Projection with population release over 30 days

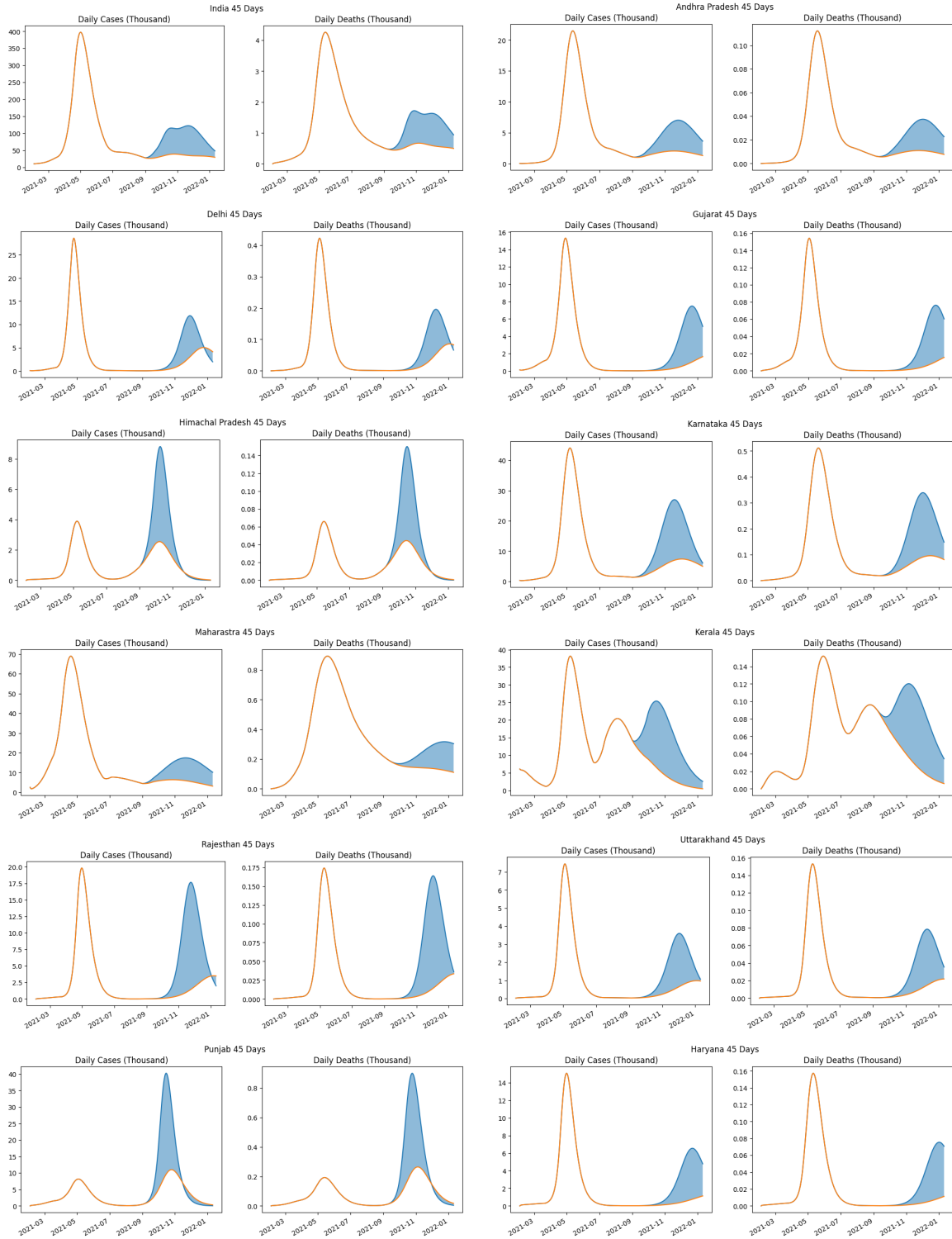


Figure 4: Projection with population release over 45 days



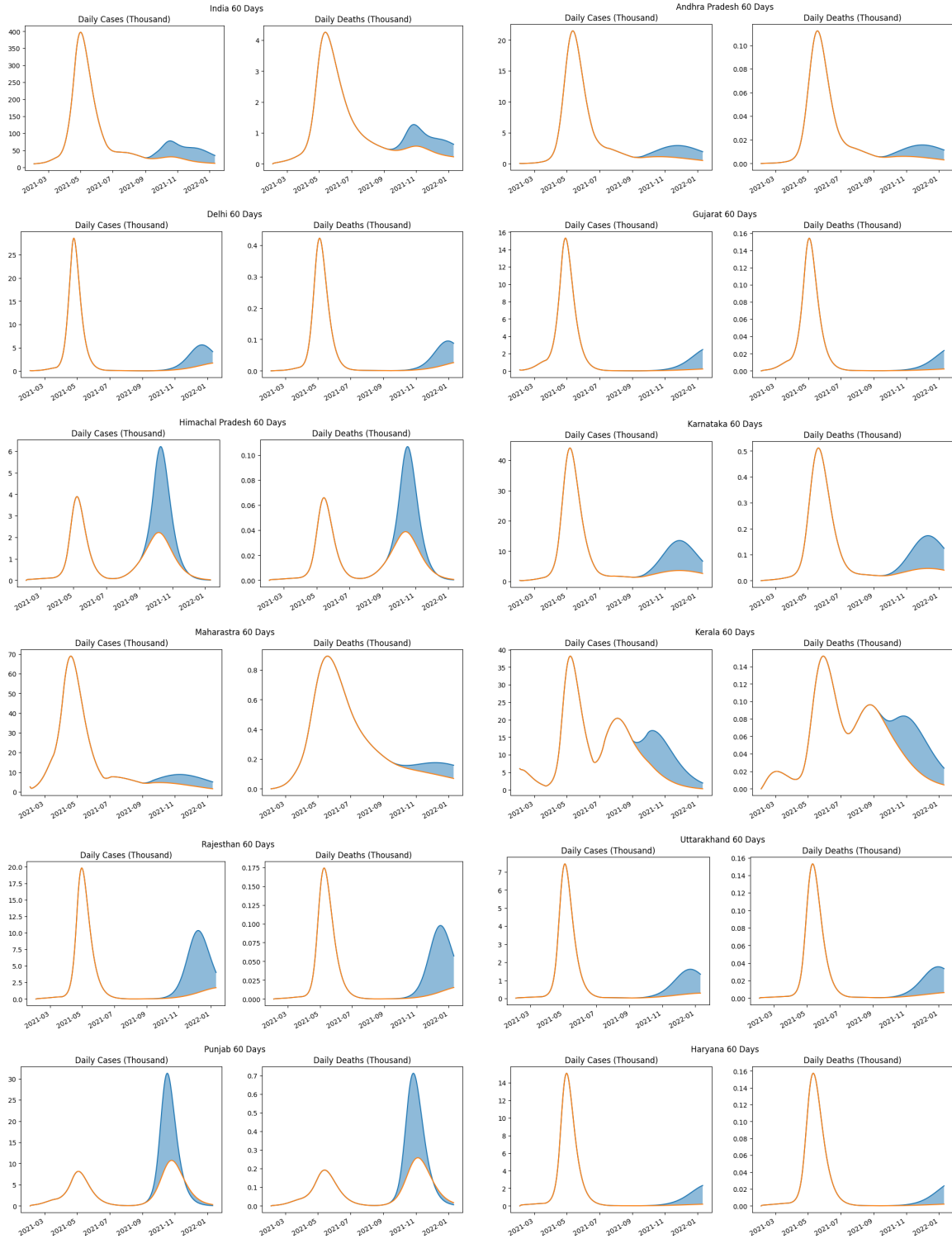


Figure 5: Projection with population release over 60 days

state	Improvement in Cases		Improvement in Deaths	
	45 Days	60 Days	45 Days	60 Days
<b>India</b>	<b>48.63%</b>	<b>68.29%</b>	<b>44.85%</b>	<b>62.89%</b>
Andaman and Nicobar	90.51%	96.10%	72.34%	78.39%
Andhra Pradesh	56.70%	78.51%	57.44%	78.62%
Arunachal Pradesh	27.92%	39.23%	26.64%	37.42%
Assam	50.04%	68.50%	49.64%	67.75%
Bihar	86.24%	94.23%	9.44%	10.60%
Chandigarh	12.96%	19.40%	12.86%	19.25%
Chhattisgarh	82.51%	91.57%	80.91%	90.24%
Daman and Diu	69.75%	82.11%	67.77%	80.18%
Delhi	41.38%	70.31%	44.29%	75.02%
Goa	45.19%	70.06%	46.01%	71.24%
Gujarat	57.70%	90.00%	60.48%	91.25%
Haryana	58.22%	88.91%	64.97%	91.56%
Himachal Pradesh	28.86%	43.04%	28.59%	42.64%
Jammu and Kashmir	44.75%	68.56%	45.91%	69.99%
Jharkhand	52.96%	84.68%	54.95%	86.10%
Karnataka	44.00%	67.09%	46.56%	69.62%
Kerala	39.28%	56.70%	35.65%	50.80%
Ladakh	88.90%	96.03%	83.42%	90.88%
Lakshdweep	64.62%	79.62%	59.23%	73.25%
Madhya Pradesh	97.38%	99.74%	97.49%	99.67%
Maharashtra	56.99%	75.61%	49.24%	63.73%
Manipur	31.57%	43.38%	29.96%	41.18%
Meghalaya	52.02%	68.61%	50.51%	66.54%
Mizoram	18.64%	26.96%	10.82%	15.65%
Nagaland	46.97%	65.08%	45.66%	62.85%
Odisha	61.35%	74.80%	42.53%	52.65%
Puducherry	45.11%	68.90%	45.99%	70.05%
Punjab	23.05%	34.56%	23.06%	34.59%
Rajasthan	36.48%	58.08%	38.20%	61.39%
Sikkim	29.07%	40.71%	27.95%	39.15%
Tamil Nadu	78.57%	89.09%	67.19%	77.33%
Telangana	55.84%	69.43%	54.40%	67.75%
Tripura	50.79%	65.68%	46.08%	59.64%
Uttar Pradesh	83.74%	98.12%	87.50%	98.35%
Uttarakhand	45.94%	74.62%	48.59%	77.57%
West Bengal	61.95%	78.58%	61.22%	77.19%

Table 3: Improvement over 30-Day Release