Alternative Modeling Approaches

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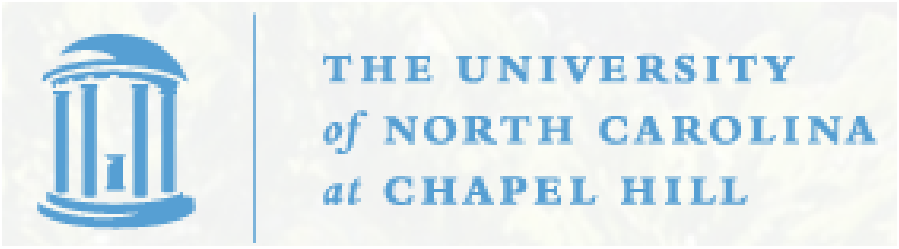


Outline

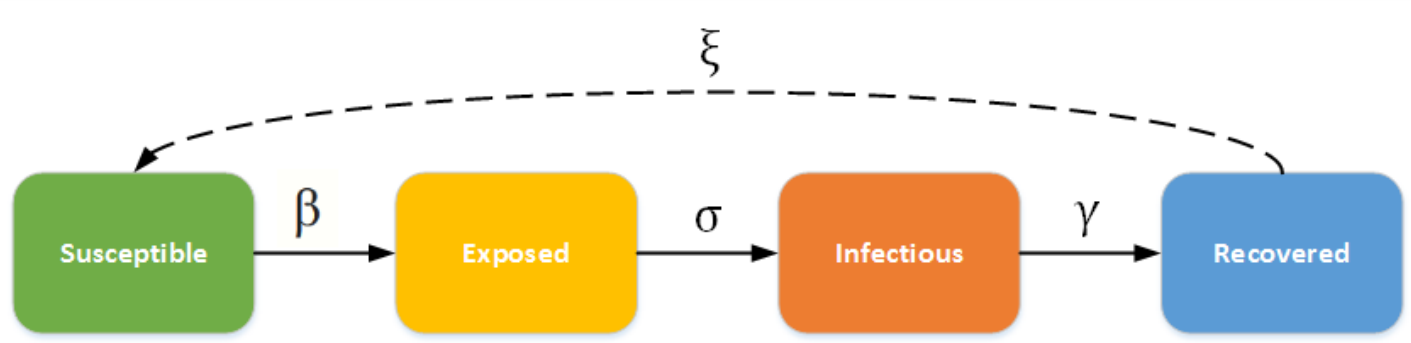
- The SIR and SEIR models
- The UNC/Duke/RTI project (Kim Powers)
- COVID-19 in India (based on SIR model)
- The University of Washington Model

SEIR (or SIR) Model

SEIR and SEIRS models

This topic describes the differential equations that govern the classic deterministic SEIR and SEIRS compartmental models and describes how to configure EMOD, an agent-based stochastic model, to simulate an SEIR/SEIRS epidemic. In this category of models, individuals experience a long incubation duration (the "exposed" category), such that the individual is *infected* but not yet *infectious*. For example chicken pox, and even vector-borne diseases such as dengue hemorrhagic fever have a long incubation duration where the individual cannot yet transmit the pathogen to others.

The SEIR/SEIRS diagram below shows how individuals move through each compartment in the model. The dashed line shows how the SEIR model becomes an SEIRS (Susceptible - Exposed - Infectious - Recovered - Susceptible) model, where recovered people may become susceptible again (recovery does not confer lifelong immunity). For example, rotovirus and malaria are diseases with long incubation durations, and where recovery only confers temporary immunity.



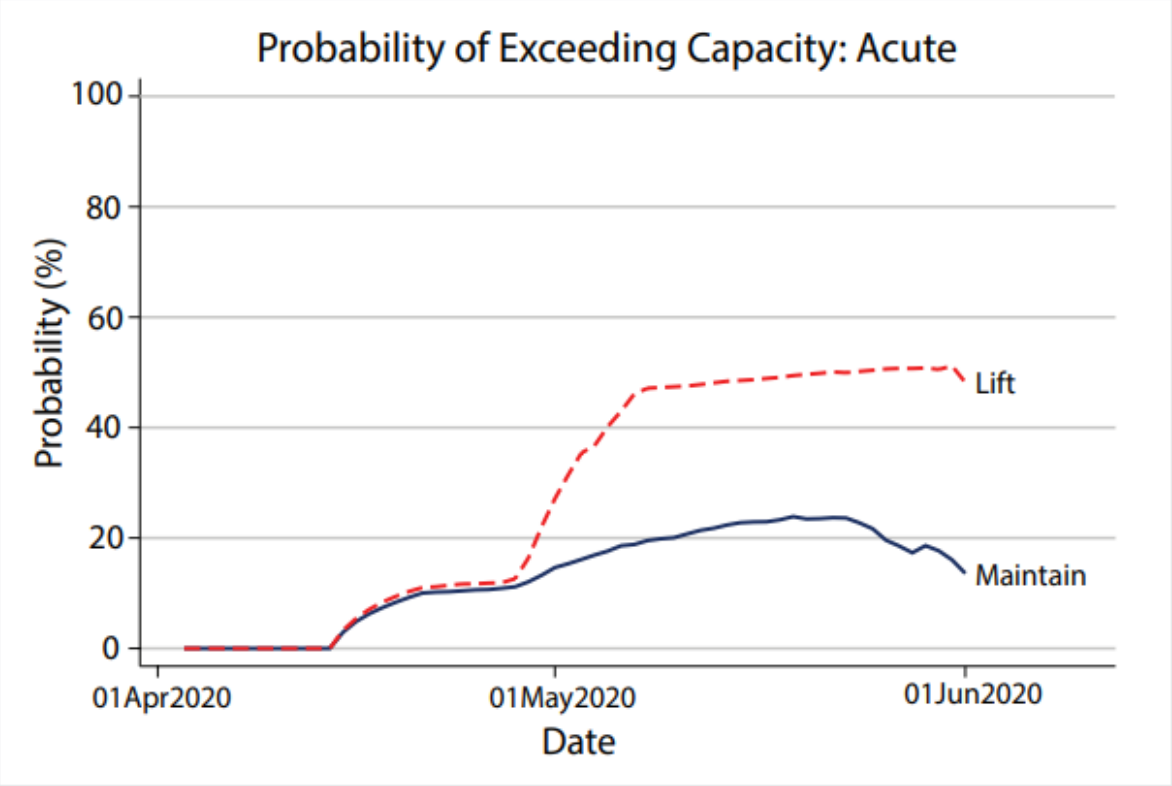
SEIR - SEIRS model

The infectious rate, β, controls the rate of spread which represents the probability of transmitting disease between a susceptible and an infectious individual. The incubation rate, σ, is the rate of latent individuals becoming infectious (average duration of incubation is $1/\sigma$). Recovery rate, $\gamma = 1/D$, is determined by the average duration, D, of infection. For the SEIRS model, ξ is the rate which recovered individuals return to the susceptible statue due to loss of immunity.

UNC/Duke/RTI Model

Preliminary Results on April 4, 2020

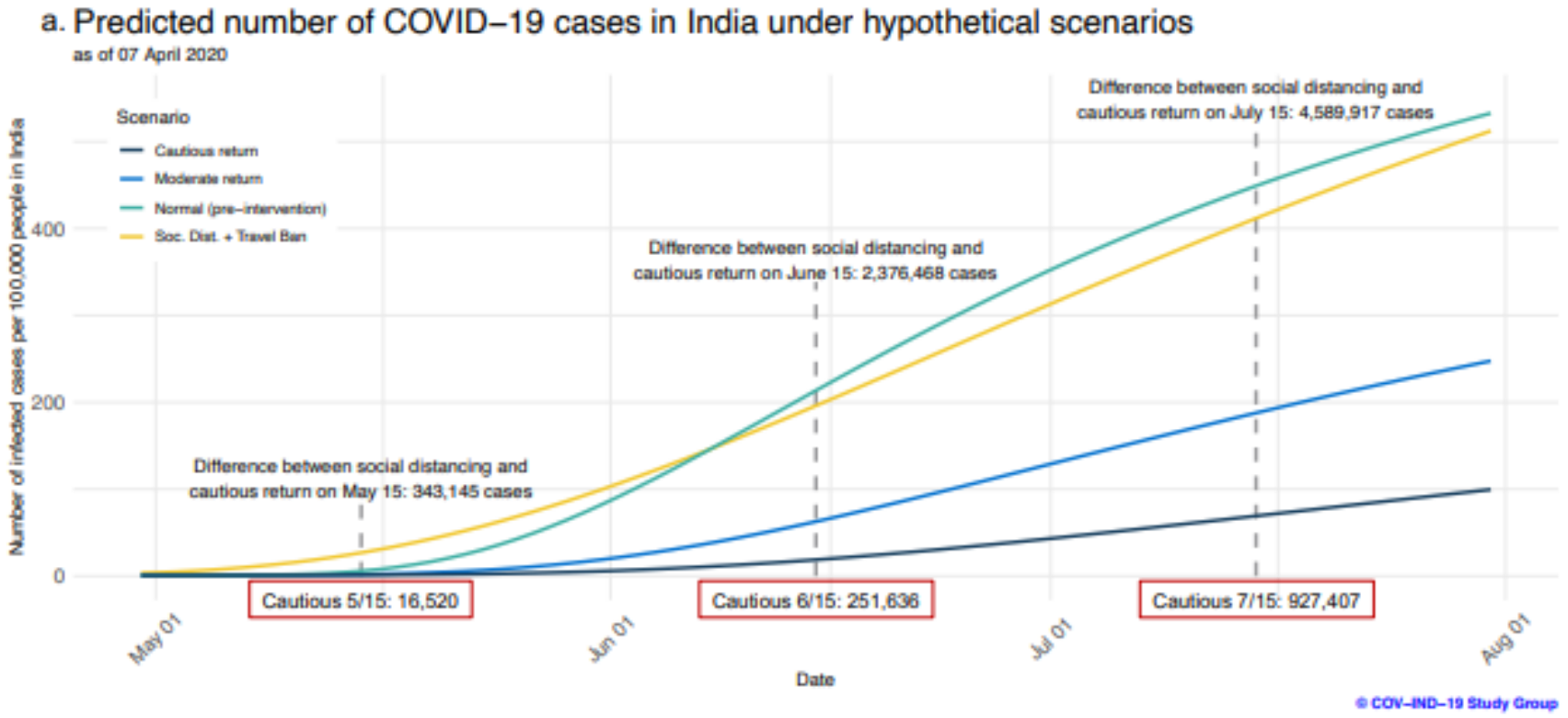
Exhibit 1 Composite estimates across three models of the probability that demand for acute hospital beds will exceed available supply in North Carolina



"Maintain" means maintain some form of aggressive social distancing policies after April and "Lift" means suspend policies after April.

eSIR Model for India

Figure 5. Long-term daily growth in case counts in India per 100,000 people assuming a 1-week delay and how that is affected by different non-pharmaceutical intervention strategies. Predicted cumulative (a) and incident (b) case counts from April 30 to July 31 from the eSIR model are shown, based on observed data until April 7. Corresponding plots for slow adherence are in **Supplementary Figure 2**.



IHME (U Wash.) Model

Statistical model for the cumulative death rate

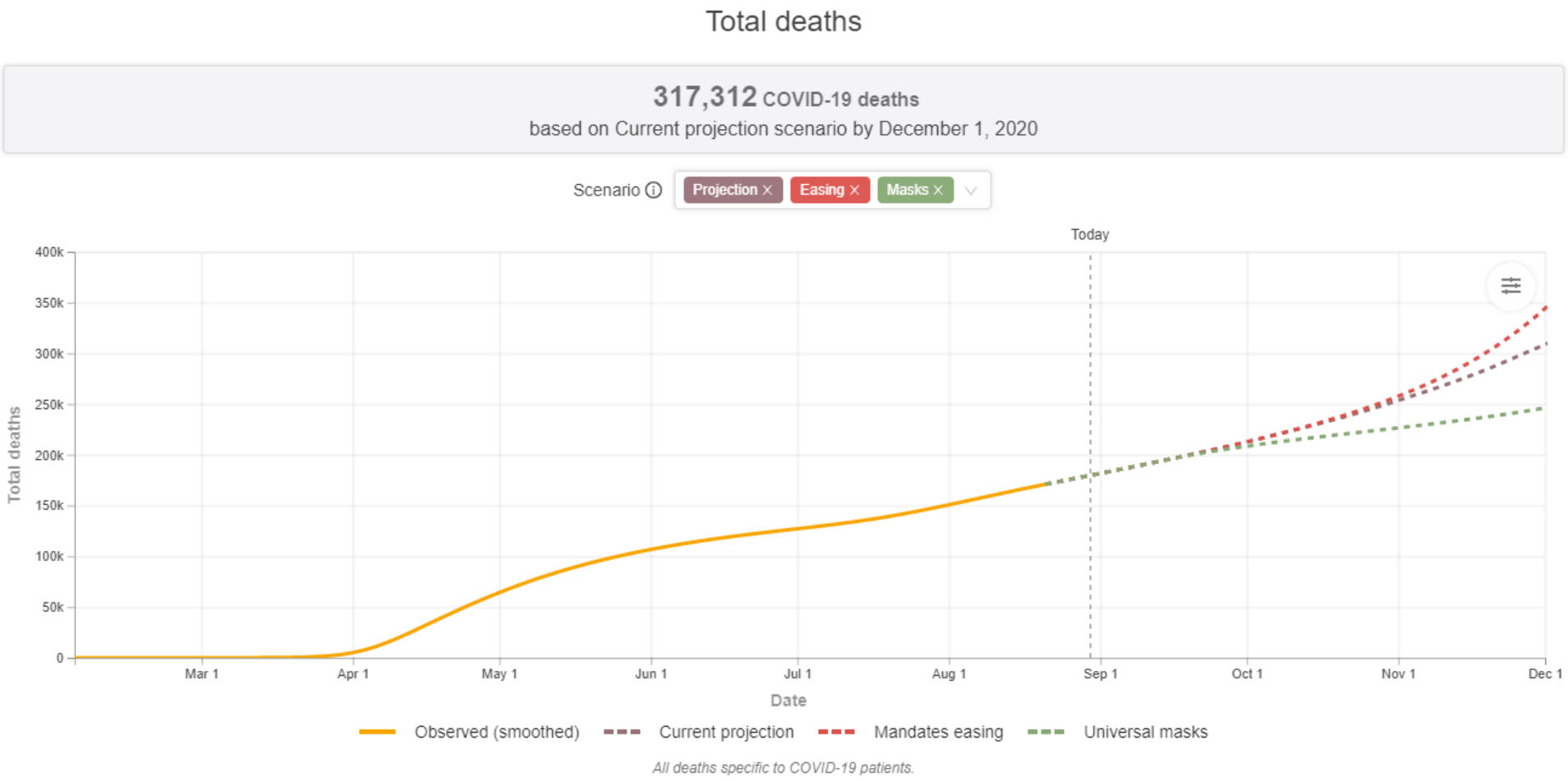
We developed a curve-fitting tool to fit a nonlinear mixed effects model to the available admin 1 cumulative death data. The cumulative death rate for each location is assumed to follow a parametrized Gaussian error function:

$$D(t;\alpha,\beta,p) = \frac{p}{2}\left(\Psi(\alpha(t-\beta)) = \frac{p}{2}\left(1 + \frac{2}{\sqrt{\pi}}\int_0^{\alpha(t-\beta)} \exp\left(-\tau^2\right) d\tau\right)\right.$$

where the function Ψ is the Gaussian error function (written explicitly above), p controls the maximum death rate at each location, t is the time since death rate exceeded 1e-15, β (beta) is a location-specific inflection point (time at which rate of increase of the death rate is maximum), and α (alpha) is a location-specific growth parameter. Other sigmoidal functional forms (alternatives to Ψ) were considered but did not fit the data as well. Data were fit to the log of the death rate in the available data, using an optimization framework described in the appendix.

Uncertainty in the model estimates is driven by two components: (1) uncertainty from fixed effect estimation and (2) uncertainty from random effects, with the latter dominant because of the high variation between locations. Uncertainty of fixed effects is estimated using asymptotic statistics derived from the likelihood. In every model, we estimated location-specific parameters

IHME (U Wash.) Model



If you have questions or feedback ..

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