Weekly_SA_Provincial_COVID_19_Report

August 3, 2020

1 SARAO South Africa Provincial Epidemiological Model for COVID-19

This report summarises the results of an epidemiological model to estimate the near-term upper and lower bounds for total demand for hospitalization per province in South Africa due to COVID-19, to aid with production and logistics planning for the National Ventilator Project executed by SARAO.

In our National Model work, we provide long-range (1-year) national forecasts by varying R_t over plausible values intended to capture both goverment social interventions and heterogenous social compliance, within a still-unknown epidemiological landscape.

Here, we instead use the near-past to predict the near-future: for each independent provincial model, we fit an exponential function to the previous 14 days of case data, and run 1000 scenarios, where the value of R_t is allowed to vary within the standard deviation of this fit. Importantly, model are instantiated with current *reported* data, and thus predict future reported parameters. Ensembles are reported with 68 percentile confidence intervals, as well as histograms through the ensembles at a 30-day horizon.

Our models have several limitations. We rely on data from `https://github.com/dsfsi/covid19za`. We assume no inter-provincial mixing. We do not model heterogenous infectivity, such as 'superspreader' scenario effects, unknown community immunity, etc. These are short-term models: long-term predictions should take in to account government interventions and community compliance on the effective values $R_t(t)$ can assume.

Disclaimer: the models described here are intended for general information purposes only. The authors accept no liability or responsibility for the use of the information in this document and provide no warranty regarding any results, data or code herein.

2 Provincial Ensembles

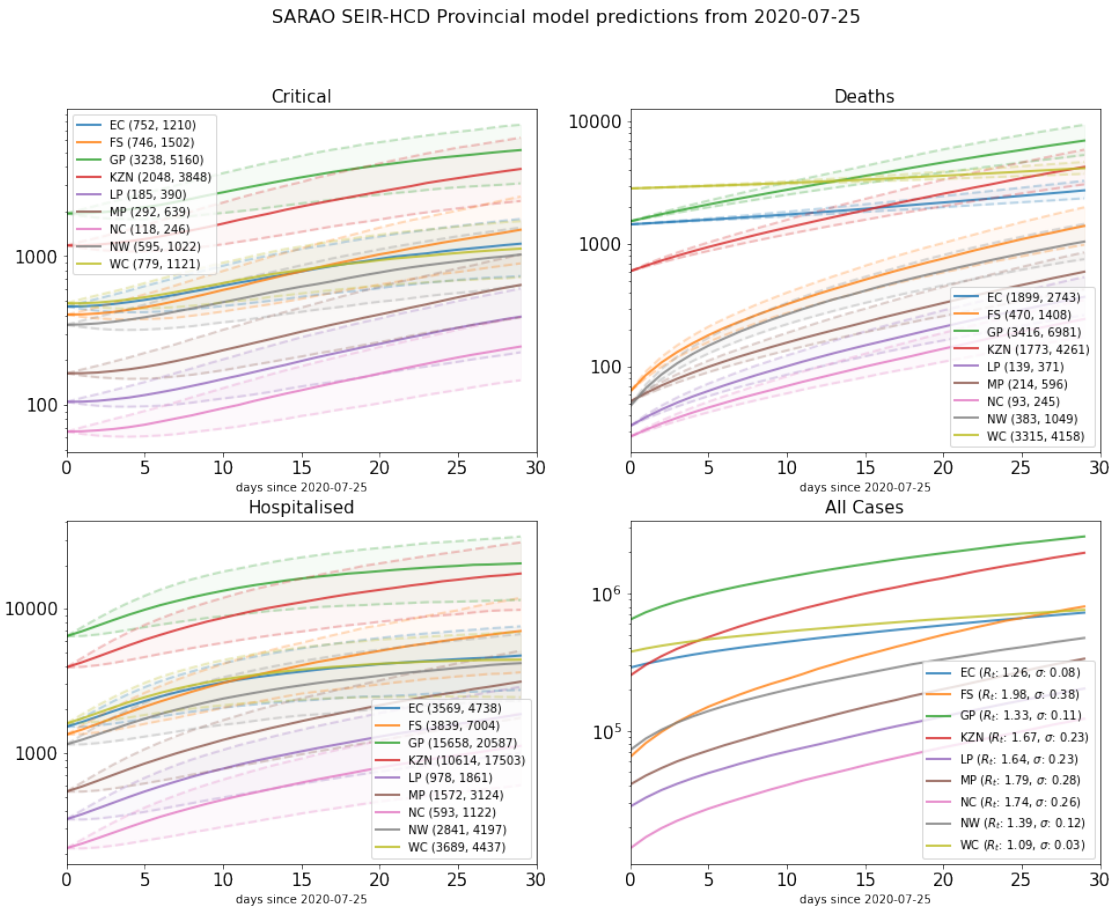


Figure 1: *An ensemble of epidemic scenarios on a provincial level, run starting from this report's date. An exponential function is fit to the previous two week's (from the report date) recorded cases to derive R_t, which is then varied within the standard deviation of the fit over 1000 scenarios. In each of the figures, the y-axis indicates the number of people in each epidemiological state (Top-left: ICU, Top-right: deaths, Bottom-Left: hospitalisations, Bottom-Right: Total Cases). Solid lines indicate the median value of all the simulations, and the 68th percentiles are shown shaded between dashed lines. Total cases includes all cases, not just those testing positive; i.e. it includes asymptomatic, symptomatic, tested and untested cases, as well as recovered and deceased.*

The median values of our predictions at 14 and 30 days respectively are shown in parentheses following the province name in the legend, except for the bottom-right panel, which shows the R_t value (and s.d.) fit to recorded cases (from https://github.com/dsfsi/covid19za) over the previous two weeks.

2.1 Provincial SEIR-HCD Model

An individual SEIR-HCD model is instantiated per province with current reported data, and an ensemble of 1000 models is run for 30 days from this report's date. For details and an extended explanation of the base model, please see our National Model Report.

In the provincial model shown in the figures above and the table below, the numbers given for each compartment will reflect the predicted number of individuals reported in the corresponding epidemiological state.

Province	population	R_t (σ)	Hosp. / Crit. at day 14	Hosp. / Crit. at day 30	Provincial hosp. ratio
Gauteng	15176115	1.33 (0.11)	15658 / 3238	20587 / 5160	1.00
KwaZulu-Natal	11289086	1.67 (0.23)	10614 / 2048	17503 / 3848	0.68
Free State	2887465	1.98 (0.38)	3839 / 746	7004 / 1502	0.25
Western Cape	6844272	1.09 (0.03)	3689 / 779	4437 / 1121	0.24
Eastern Cape	6712276	1.26 (0.08)	3569 / 752	4738 / 1210	0.23
Northwest	4027160	1.39 (0.12)	2841 / 595	4197 / 1022	0.18
Mpumalanga	4592187	1.79 (0.28)	1572 / 292	3124 / 639	0.10
Limpopo	5982584	1.64 (0.23)	978 / 185	1861 / 390	0.06
Northern Cape	1263875	1.74 (0.26)	593 / 118	1122 / 246	0.04

Table 1: *Key provincial predictions. The current value of R_t per province is calculated from recorded cases over the previous 14 days using an exponential fit. This value of R_t is allowed to vary within the standard deviation of this fit for 1000 ensemble runs. Both R_t and its standard deviation are tabled. Median predictions for hospitalisation / critical compartment numbers are tabled for 14 and 30 days, as well as the relative ratio of predicted hospitalisations at day 14.*

Provincial populations and cases are from https://github.com/dsfsi/covid19za.

2.2 Recorded Deaths

The following two figures show, for reference, the recorded deaths in each province on a logarithmic and a linear scale respectively since 1 April 2020 (from https://github.com/dsfsi/covid19za).

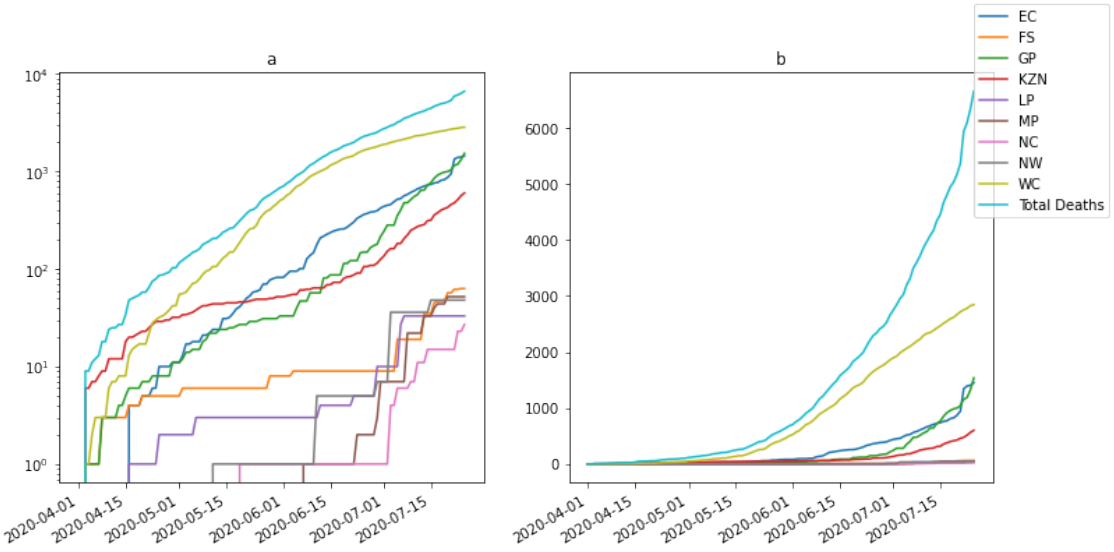


Figure 2: *Recorded deaths per province on a (a) logarithmic, and (b) linear scale since 1 April 2020 (from https://github.com/dsfsi/covid19za)*

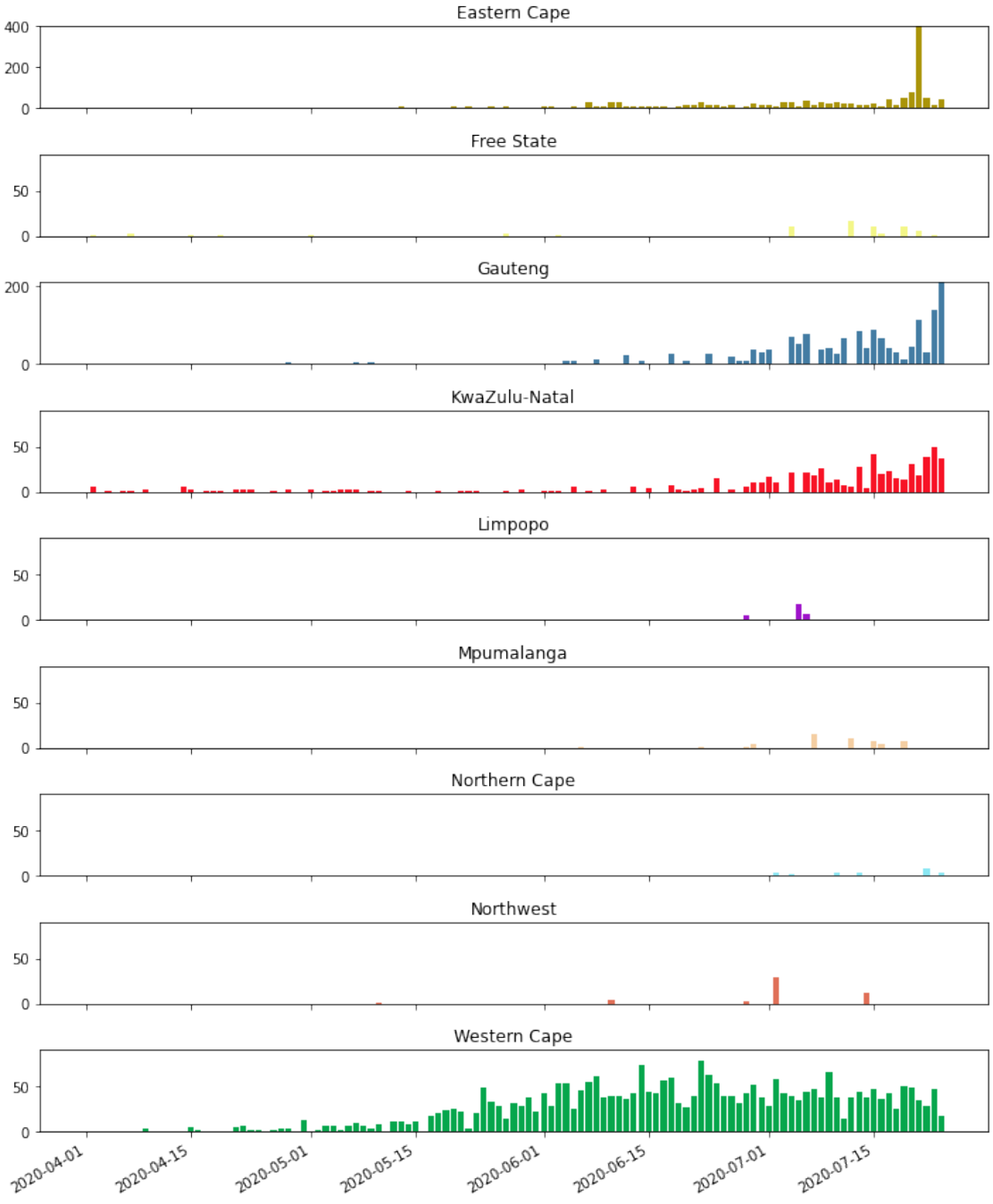
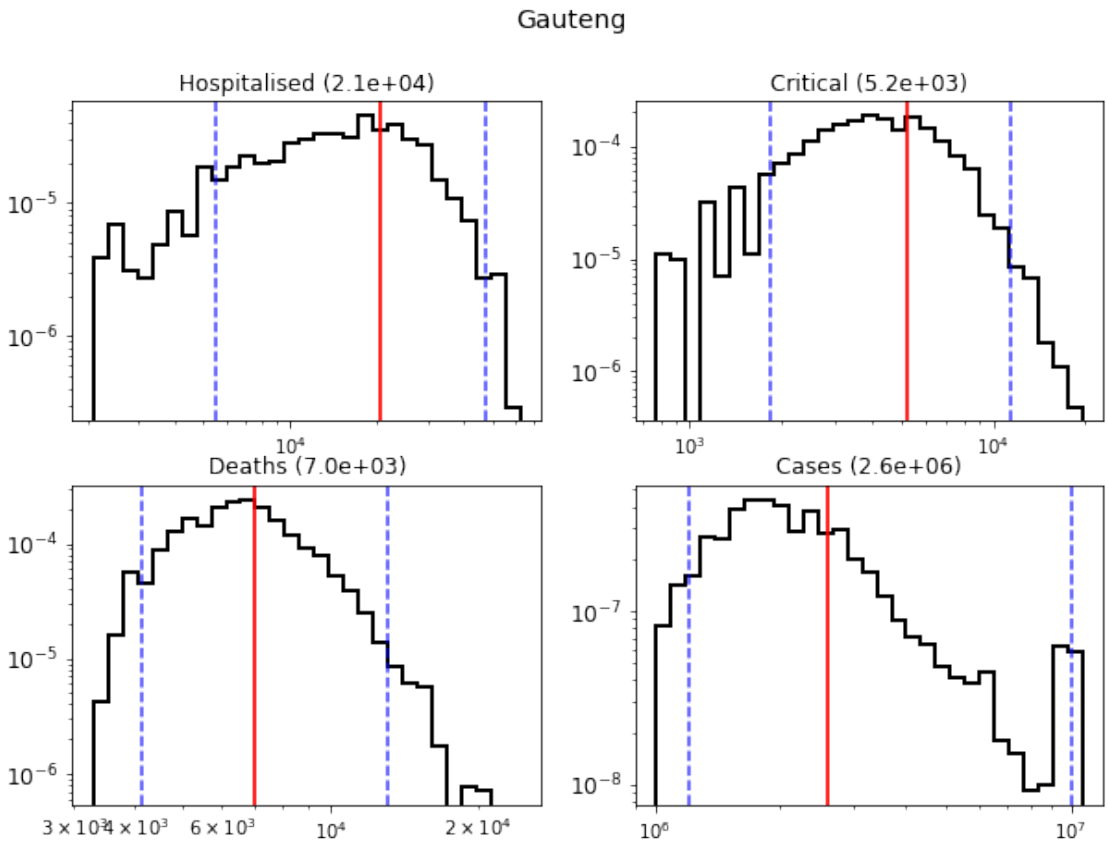
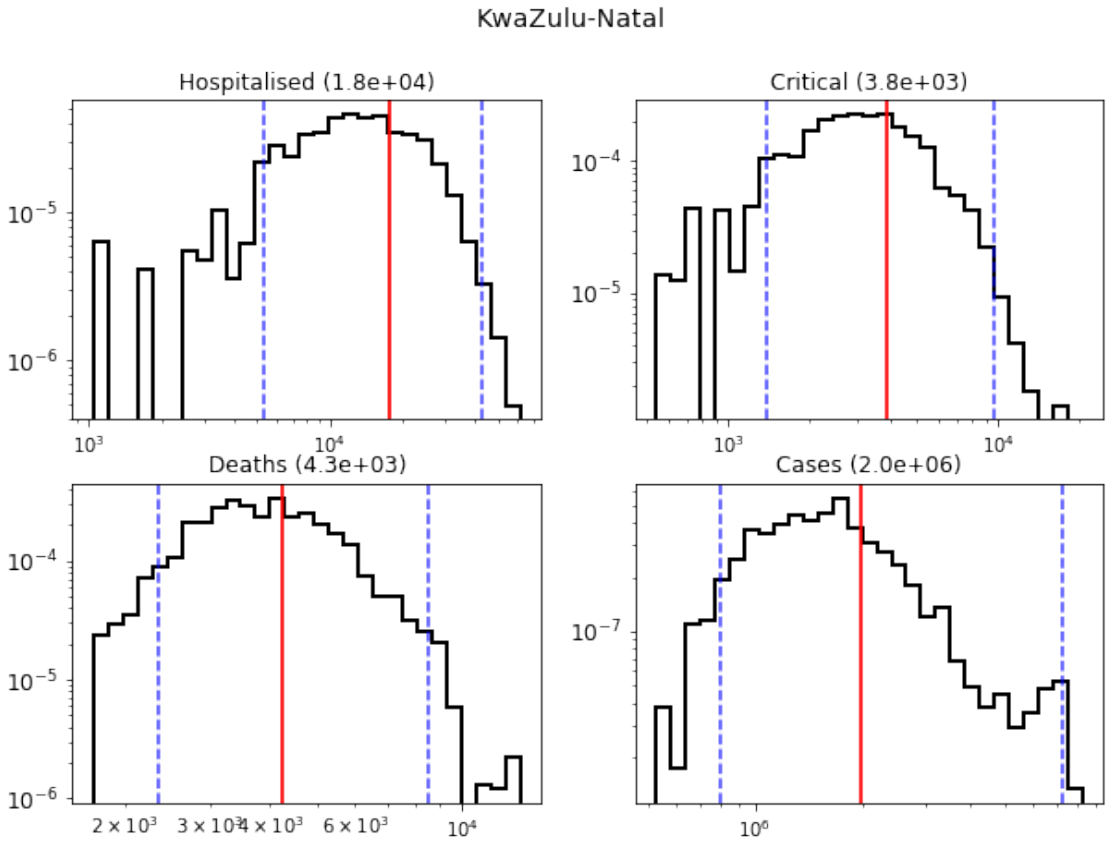
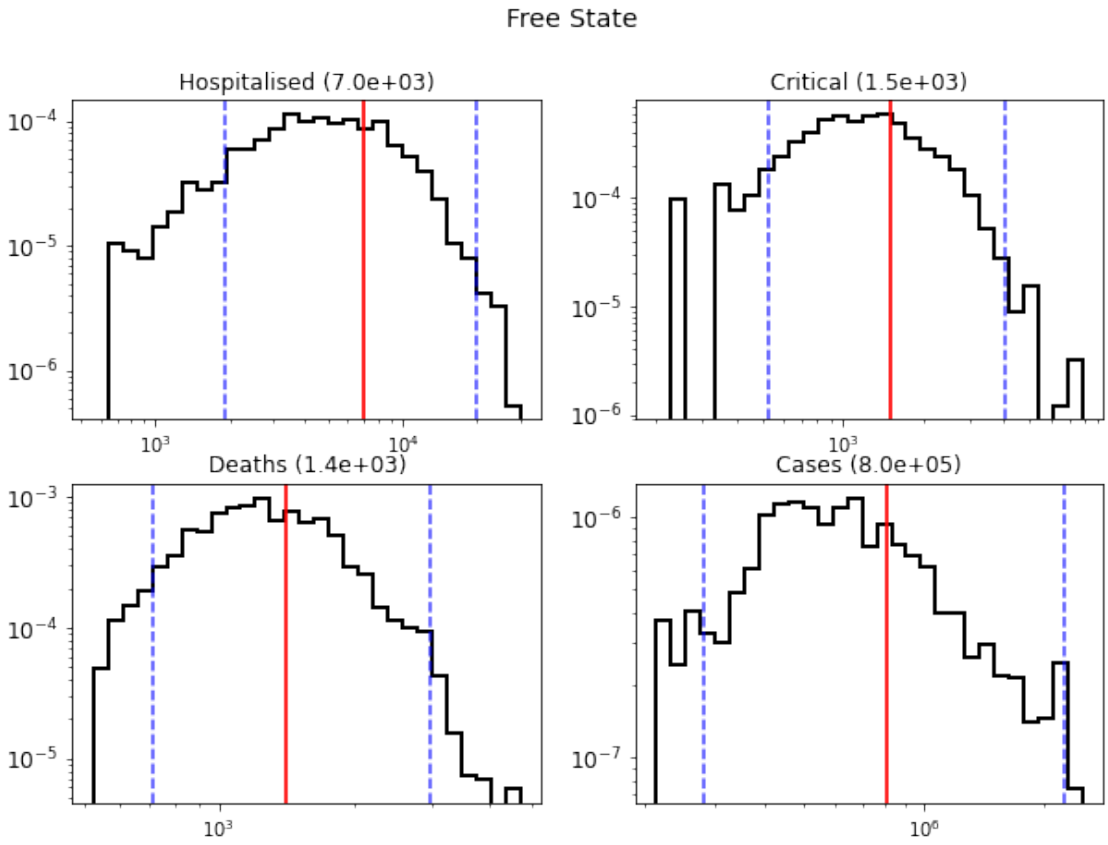


Figure 3: *Daily recorded deaths per province since 1 April 2020.*

2.3 Histograms




KwaZulu-Natal
Hospitalised (1.8e+04)
Critical (3.8e+03)
Deaths (4.3e+03)
Cases (2.0e+06)


Free State
Hospitalised (7.0e+03)
Critical (1.5e+03)
Deaths (1.4e+03)
Cases (8.0e+05)

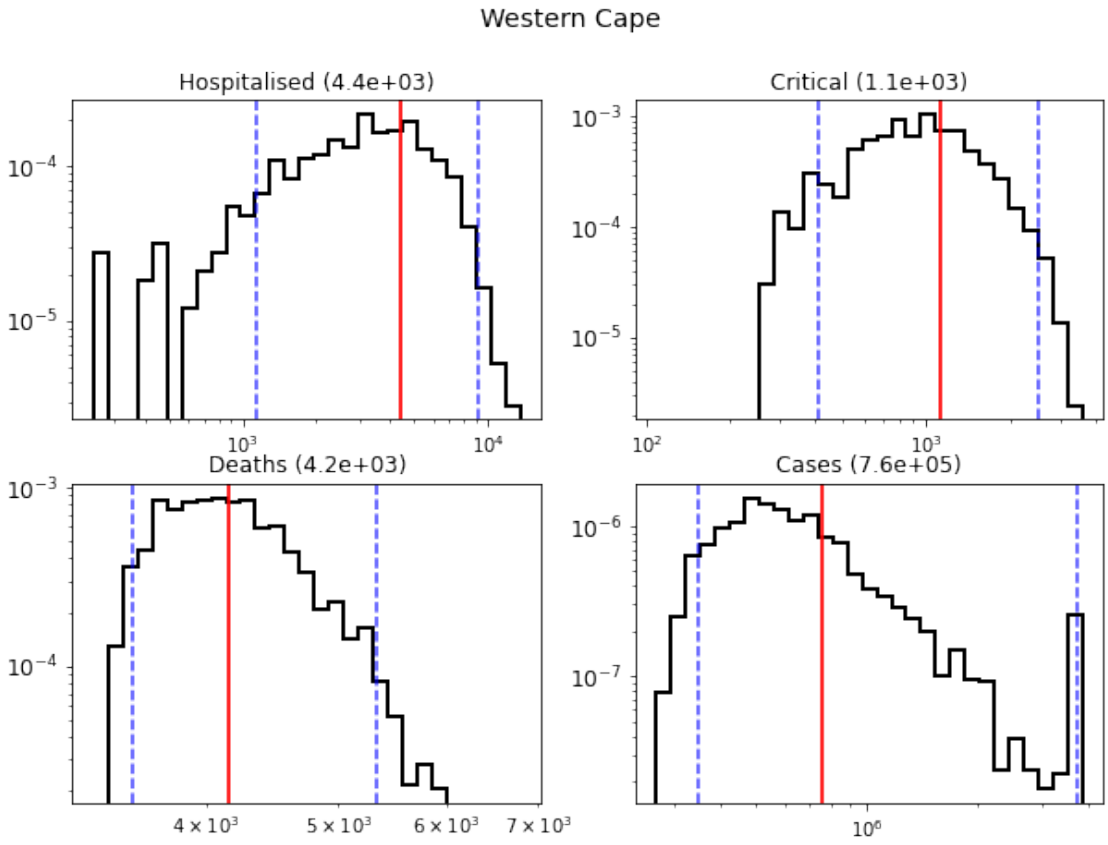


Figure 4: *Histograms through the ensembles at day 30 of predicted concurrent hospitalised individuals, critical individuals, predicted deaths, and total cases respectively from left to right and top to bottom for each of the top four provinces ranked by number of hospitalisations at day 14. Vertical lines are 2.5th (blue dotted, left), 50th (median, red solid), and 97.5th percentiles (blue dotted, right).*

2.4 Model Verification

Province	$R_t(\sigma)$ on 2020-07-11	Deaths on 2020-07-11	Prediction (std. err.) for 2020-07-25	Recorded on 2020-07-25
Gauteng	1.76 (0.29)	580	2322 (488)	1535
KwaZulu-Natal	1.88 (0.35)	273	760 (135)	602
Free State	2.25 (0.54)	19	127 (32)	63
Western Cape	1.17 (0.05)	2333	2870 (144)	2845
Eastern Cape	1.52 (0.18)	664	1136 (134)	1450
Northwest	1.81 (0.30)	36	244 (60)	48
Mpumalanga	2.26 (0.51)	22	97 (23)	52
Limpopo	2.02 (0.36)	33	83 (15)	33

Province	$R_t(\sigma)$ on 2020-07-11	Deaths on 2020-07-11	Prediction (std. err.) for 2020-07-25	Recorded on 2020-07-25
Northern Cape	2.11 (0.44)	11	37 (8)	27

Table 2: *Model Verification: median model predictions (std. err.) for today's date calculated from data 14 days ago compared to reported provincial deaths. The columns show, respectively, the province name, the historical $R_t(\sigma)$ from two weeks ago, recorded deaths on that date, the model prediction, recorded deaths at the prediction date, and the percentage error.*

3 National Model

Shown below for reference are the predictions of the SARAO NVP National Model ensembles.

The figure below shows a full ensemble of 2000 epidemic runs starting on 1 April 2020 (Day 0). On the y-axis we plot the number of people in each state (Top-left: ICU, Top-right: deaths, Bottom-Left: hospitalisations, Bottom-Right:Total Cases).

Our models have peaks that vary by up to about 100 days. Magenta lines indicate the median value of all the simulations. Models with average Rt > 2 imply more than 80% of the population get infected. The black line on the fatalities curve shows actual South African deaths. Note that most of our models struggle to match observed deaths to the current time, suggesting that we may be underestimating the fatality rate.

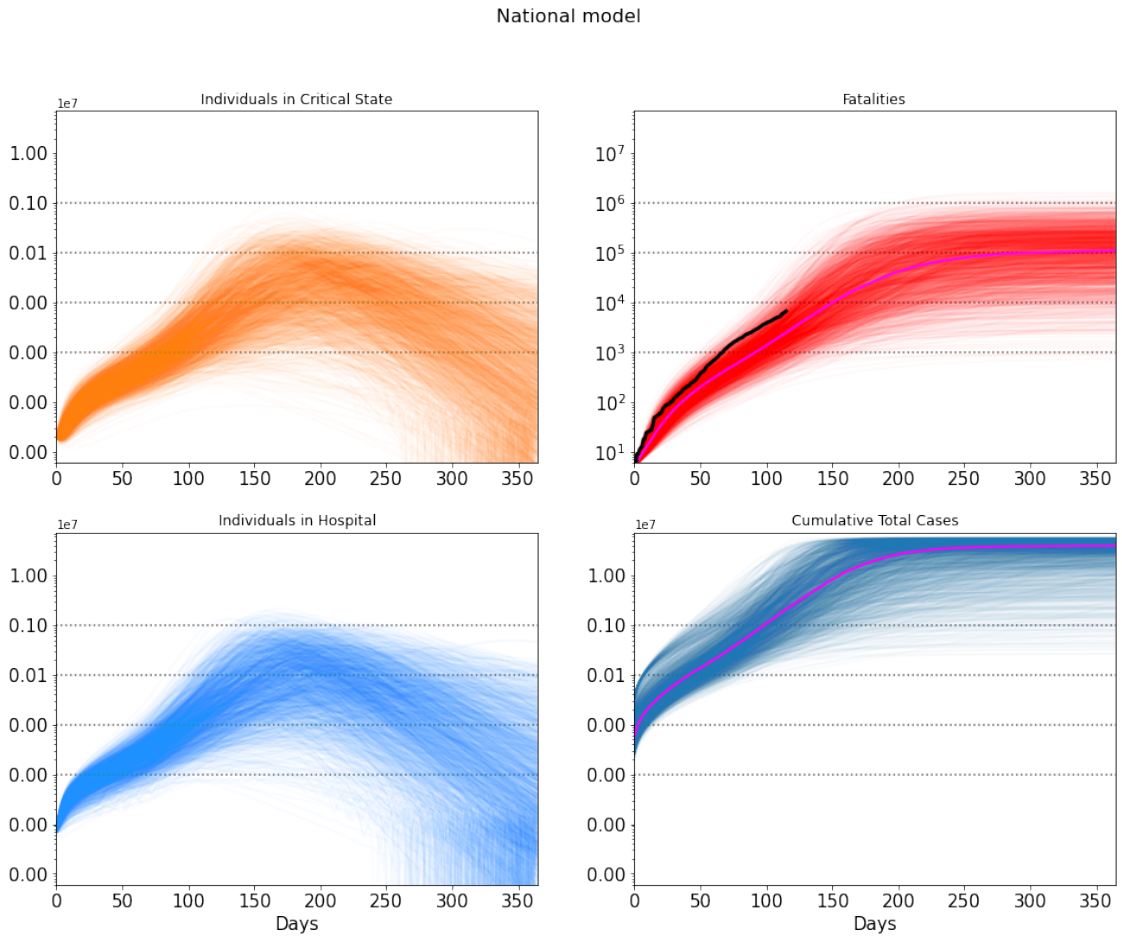


Figure 5: *The full ensemble of 2000 National Model epidemic runs starting on 1 April 2020 (Day 0). On the y-axis we plot the number of people in each state (Top-left: ICU, Top-right: deaths, Bottom-Left: hospitalisations, Bottom-Right:Total Cases). Note how the models have peaks that vary by up to about 100 days. Magenta lines indicate the median value of all the simulations. Note that models with average $R_t > 2$ typically imply more than 80% of the population get infected. The black line on the fatalities curve shows actual South African deaths. Note that most of our models struggle to match observed deaths suggesting that we may be underestimating the fatality rate. Total cases includes all cases, not just those testing positive; i.e. it includes asymptomatic, symptomatic, tested and untested cases, as well as recovered and deceased.*