NIPH
Norwegian Institute of Public Health

Situational awareness and forecasting for Norway

FHI COVID-19 modelling team

Week 48, 24 November 2020

Highlights:

- **National epidemiological situation:** Our models evaluate the present situation as improved and essentially stable. The reproduction number R_9 acting in our changepoint model from 5 November is estimated to be 1.01 (median, 95% CI 0.93-1.12), lower than our estimates from a week ago. The estimated probability that R_9 is larger than 1 is 57.5%. From this week, the SMC model, similarly to the changepoint model, also uses the test data in the estimation of model parameters, in addition to the hospitalisation data. SMC estimates the 7-days averaged reproduction number one week ago to be 1.05 (95% CI 0.75-1.40). The model shows a clear decreasing trend since the interventions applied at the end of October and reinforced at the beginning of November. In this model, the estimated probability that the daily reproduction number one week ago was above 1 is 60.3%. Since the start of the epidemic, we estimate that in total 97.000 (95% CI 86.000- 109.000) persons in Norway have been infected. We estimate the number of infected individuals to be now at the same level as at the top in April. The current estimate of the detection probability is $\tilde{4}0\%$.
- **National forecasting:** In one week, we estimate 1.300 new cases per day (95%CI 1.100-1.800), and a prevalence (total number of infected people in Norway) of 8.000 (95% CI 7.000-11.000), less than a week ago. Hospitalisations and patients on ventilator treatment in one week are estimated to be 200 (median 95% CI 160-250) and 29 (median 95% CI 20-40), respectively; the corresponding three-week projections are (95% CI 160 - 290) and (95% CI 20 - 46). Hospitalisations are delayed to the onset of infection and are therefore still slightly increasing. Note: Our model has overestimated hospitalisations in recent weeks. A long-term scenario projection with the current R suggests a peak in February 2021. Our predictions are more reassuring than a week ago. None of the simulations exceeded 500 required ventilator beds.
- **Regional epidemiological situation and forecasting:** The model shows large regional differences. In some counties we predict a stable situation, in others a slight worsening or improvement. Uncertainty is large, except for the most populated counties. The counties with highest current reproduction numbers (since 26 October) are Oslo, estimated at 1.27 (95% CI 0.99-1.68) with a slight reduction since last week, Innlandet 1.38 (95% CI 0.32-2.03), relatively stable with a considerable uncertainty, and Viken 1.34 (95% CI 1.08-1.56), with a slight worsening since last week. Agder shows a worsening too from last week. The lowest mean reproduction number is estimated in Nordland 0.69 (95% CI 0.05-1.62), with high uncertainty. See table 5 for information about all counties. Oslo: The number of new cases per day is estimated to be 450 (mean, 95% CI 257 - 721) on 29 November, and in three weeks 670 (95% CI 306-1337). Hospital prevalence in one week is estimated to be 60, and in three weeks 68 (95% CI 33-119). See Table 9 and Table 10 for information about expected need for patient beds.
- **Telenor mobility data, local mobility and foreign roamers:** Inter-municipality mobility, measured as outgoing mobility of mobile phones from each municipality is decreasing since the middle of October. Now it is at a level similar to the summer period, but higher than during the March lockdown. Analysis of foreign roamers (visitors) has stabilised in the last weeks. Polish and Lithuanian roamers show high visiting levels throughout 2020, still with an increasing trend in Oslo.

What this report contains:

This report presents results based on a mathematical infectious disease model describing the geographical spread of COVID-19 in Norway. The model consists of three layers:

- Population structure in each municipality.
- Mobility data for inter-municipality movements (Telenor mobile phone data).
- Infection transmission model (SEIR-model)

The model produces estimates of the current epidemiological situation at the municipality, county (fylke), and national levels, a forecast of the situation for the next three weeks, and a long term prediction. We run three different models built on the same structure indicated above: (1) a national changepoint model, (2) a regional changepoint model and (3) a national Sequential Monte Carlo model, named SMC model.

How we calibrate the model: The national changepoint model is fitted to Norwegian COVID-19 hospital incidence data from March 10 until yesterday, and data on the laboratory-confirmed cases from May 1 until yesterday. We do not use data before May 1, as the testing capacity and testing criteria were significantly different in the early period.
Note that the results of the national changepoint model are not a simple average or aggregation of the results of the regional changepoint model because they use different data. The estimates and predictions of the regional model are more uncertain than those of the national model. The regional model has more parameters to be estimated and less data in each county; lack of data limits the number of changepoints we can introduce in that model. In the regional changepoint model, each county has its own changepoints and therefore a varying number of reproduction numbers. Counties where the data indicate more variability, have more changepoints.
The national SMC model is currently calibrated only to the hospitalisation incidence data (same data as described above). We are working on extending it to use also the test data.

Telenor mobility data: The mobility data account for the changes in the movement patterns between municipalities that have occurred since the start of the epidemic.

How you should interpret the results: The model is stochastic. To predict the probability of various outcomes, we run the model many times in order to represent the inherent randomness.
We present the results in terms of mean values, 95% confidence intervals, medians, and interquartile ranges. We emphasise that the confidence bands might be broader than what we display, because there are several sources of additional uncertainty which we currently do not fully explore: firstly, there are uncertainties related to the natural history of SARS-CoV-2, including the importance of asymptomatic and presymptomatic infection. Secondly, there are uncertainties related to the timing of hospitalisation relative to symptom onset, the severity of the COVID-19 infections by age, and the duration of hospitalisation and ventilator treatment in ICU. We continue to update the model assumptions and parameters in accordance with new evidence and local data as they become available. A full list of all updates can be fount at the end of this report.
Estimates of all reproduction numbers are uncertain, and we use their distribution to assure appropriate uncertainty of our predictions. Uncertainties related to the model parameters imply that the reported effective reproductive numbers should be interpreted with caution.

When we forecast beyond today, we use the most recent reproduction number for the whole future, if not explicitly stated otherwise.

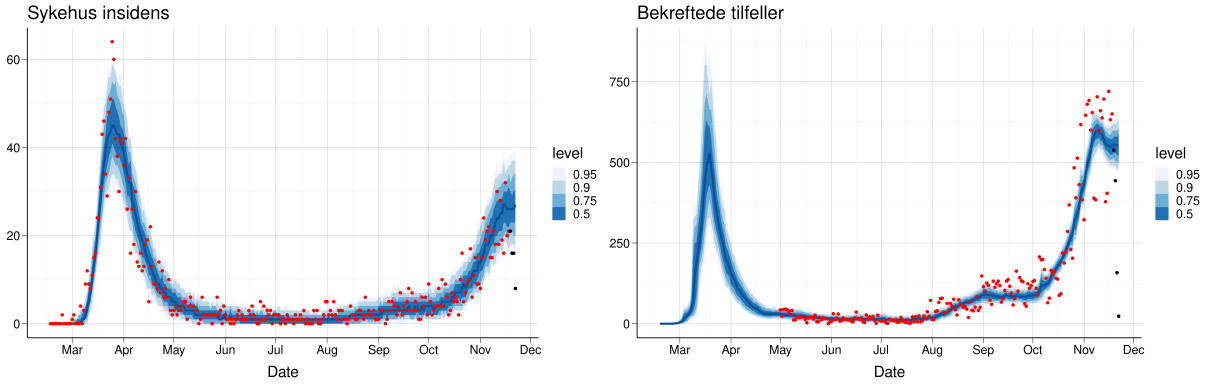
In this report, the term patient in ventilator treatment includes only those patients that require either invasive mechanical ventilation or ECMO (Extracorporeal membrane oxygenation).

1 Estimated national reproduction numbers

Calibration of our national changepoint model to hospitalisation incidence data and test data leads to the following estimates provided in table 1. Figure 1 shows the estimated daily number of COVID-19 patients admitted to hospital (1a) and the estimated daily number of laboratory-confirmed SARS-CoV-2 cases (1b), with blue medians and interquantile bands, which are compared to the actual true data, provided in red. The uncertainty captures the uncertainty in the calibrated parameters in addition to the stochastic elements of our model and the variability of other model parameters.

Table 1: Calibration results

Parameter	Mean	Median	Confidence interval (95 %)	Period
R0	3.34	3.30	(2.61-4.22)	Until March 14
R1	0.45	0.45	(0.37-0.52)	From March 15 to April 19
R2	0.82	0.83	(0.5-1.17)	From April 20 to May 10
R3	0.83	0.86	(0.49-1.07)	From May 11 to June 30
R4	0.84	0.84	(0.36-1.31)	From July 1 to July 31
R5	1.08	1.08	(0.86-1.29)	From Aug 1 to Aug 31
R6	0.93	0.93	(0.8-1.05)	From Sept 1 to Sept 30
R7	1.26	1.25	(1.05-1.51)	From Oct 1 to Oct 25
R8	1.37	1.38	(1.07-1.67)	From Oct 26 to Nov 4
R9	1.02	1.01	(0.93-1.12)	From Nov 5

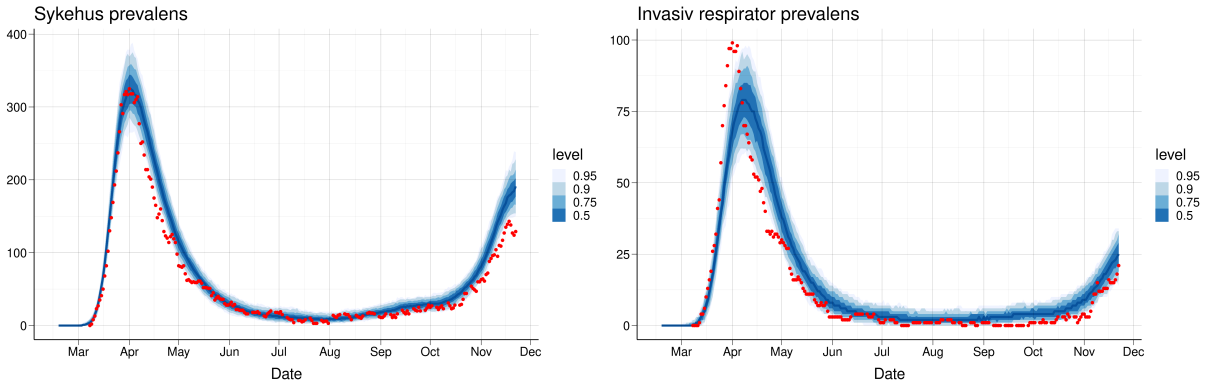


(a) Hospital admissions

(b) Test data

Figure 1: A comparison of true data (red) and predicted values (blue) for hospital admissions and test data. The last four data points (black) are assumed to be affected by reporting delay. B) Comparison of our simulated number of positive cases, with blue median and interquartile bands to the actual true number of positive cases, provided in red. The uncertainty captures the uncertainty in the calibrated parameters, in addition to the stochastic elements of our model and the variability of other model parameters. Note that we do not capture all the uncertainty in the test data–our blue bands are quite narrow. This is likely because we calibrate our model parameters on a 7-days moving average window of test data, instead of daily. This is done to avoid overfitting to random daily variation. Moving averages over 7 days are less variable than the daily data.

In figure 2, we show how our national model fits the national hospital prevalence data (2a) and the daily number of patients receiving ventilator treatment (2b). Those data sources are not used to estimate the parameters, and can therefore be seen as a validation of the model assumptions.



(a) Hospital prevalence

(b) Ventilator prevalence

Figure 2: A comparison of true data (red) and predicted values (blue) for hospital and respirator prevalence.

1.1 National SMC-model: Estimated daily reproduction numbers

In the SMC-model, we allow for estimation of a different reproduction number for each day t. To reduce spurious fluctuation, we report a 7-days moving average, $R(t)$, representing the average reproduction number for the whole week before day t. However, until March 8 we keep the reproduction number constant. By assuming a time varying reproduction number $R(t)$, we can detect changes without introducing explicit changepoints. Thus, we can easier detect unexpected changes.

The SMC model uses the daily number of new admissions to hospital and the daily number of positive and negative lab-confirmed tests, to estimate all its parameters. Because of the time between infection and the possibility to be detected as positive by a test, and because if a delay in reporting tests, we can trust the estimated reproduction numbers until a week before the end of the data (today).

The figure below shows the SMC estimate of the 7-day-average daily reproduction number $R(t)$ from the start of the epidemic in Norway and until today. In the figure we plot the 95% confidence interval and quantiles of the estimated posterior distribution of $R(t)$.

1.1 National SMC-model: Estimated daily reproduction numbers

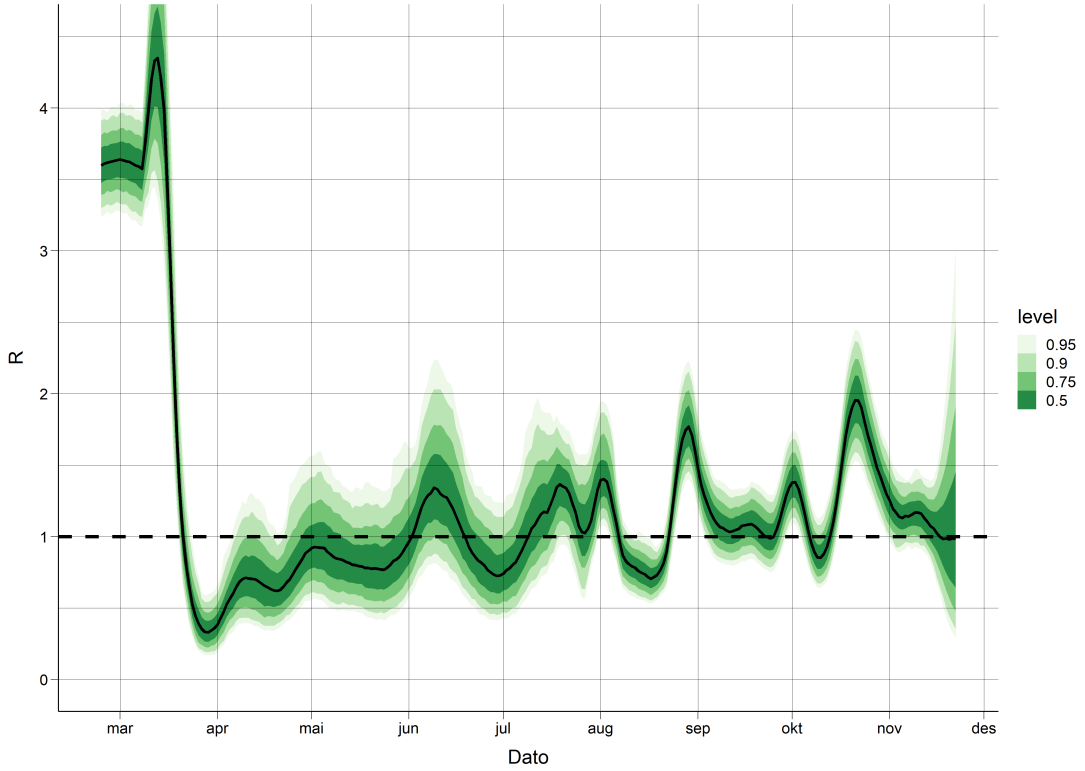


Figure 3: R(t) estimates using a Sequential Monte Carlo (SMC) approach calibrated to incidence hospitalisation and test data. The large uncertainty during the last 7 days reflects the lack of available data due to the transmission delay, test delay, time between symptoms onset and hospitalisation. The green band shows the 95% posterior credibility interval. We observe that $R(t)$ dropped below 1 in the middle of March, corresponding to the lockdown. It remained stable around 0.5 until the end of April, when it increased to 1 in the beginning of May. It then kept oscillating below and above 1, in accordance with increases and decreases of the number of new hospitalisations and number of positive test cases. $R(t)$ is sensitive to these oscillations in the data. We observe the steep increase in October and the a decrease concomitant to the first package of interventions in Norway and in the main cities. This intervention led to a decrease in the estimated reproduction number. The decrease seems to stabilise in the first days of November, when a second set of contact-reducing interventions have been decided, after which $R(t)$ drops again. As we use test data only from 1 August, the credibility interval becomes more narrow thereafter.

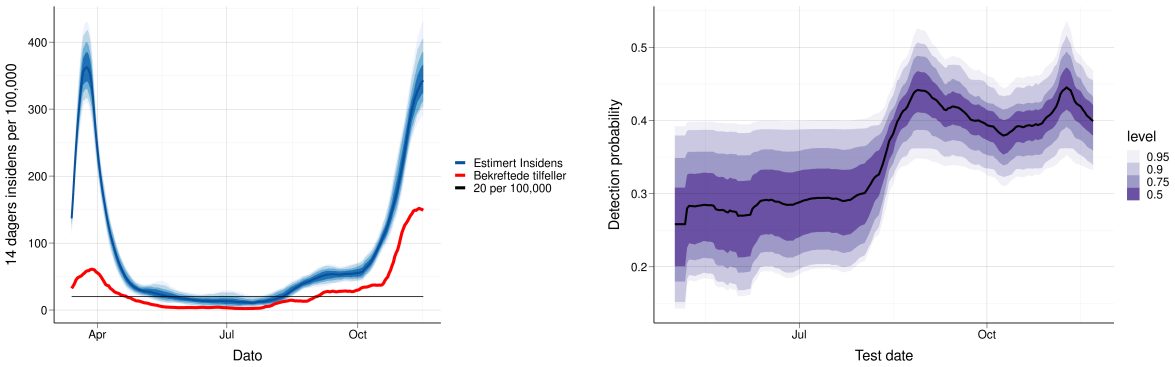
2 National estimate of cumulative (total) number of infections

The national changepoint model estimates the total number of infections and the symptomatic cases that have occurred (Table 2).
Figure 4a shows the modelled expected daily incidence (blue) and the observed daily number of laboratory-confirmed cases (red). When simulating the laboratory-confirmed cases, we also model the detection probability for the infections (both symptomatic, pre-symptomatic and asymptomatic), Figure 4b. There are two differences between this estimate of the detection probability and the previous one provided in figure 4a. In figure 4b, we calibrate our model to the true number of positive cases, instead of using the test data directly. Furthermore, in figure 4a we use a parametric model to estimate the detection probability that depends on the true total number of tests performed.

Table 2: Estimated cumulative number of infections, 2020-11-22

Region	Total	Symptomatic	No. confirmed	Fraction reported	Min. fraction
Norway	97145 (85982; 108693)	61676 (55377; 68654)	32767	34%	30%

Fraction reported=Number confirmed/number predicted; Minimal fraction reported=number confirmed/upper CI



(a) Number of laboratory-confirmed cases vs model-based estimated number of new infected individuals

(b) Estimated detection probability for an infected case per calendar day

Figure 4

3 National 3-week predictions: Prevalence, Incidence, Hospital beds and Ventilator beds

The national changepoint model estimates the prevalence and daily incidence of infected individuals (asymptomatic, pre-symptomatic and symptomatic) for the next three weeks, aggregated to the whole of Norway (table 3). In addition, the table shows projected national prevalence of hospitalised patients (hospital beds) and prevalence of patients receiving ventilator treatment (ventilator beds). The projected epidemic and healthcare burden are illustrated in figure 5.

Table 3: Estimated national prevalence, incidence, hospital beds and ventilator beds. Median/Mean (CI)

	1 week prediction (Nov 29)	2 week prediction (Dec 06)	3 week prediction (Dec 13)
Prevalence	8414/8248 (6795-10473)	8433/8229 (6384-11313)	8450/8208 (5957-12291)
Daily incidence	1356/1330 (1053-1774)	1362/1324 (994-1906)	1366/1327 (926-2035)
Hospital beds	204/202 (161-249)	210/208 (165-262)	214/213 (156-284)
Ventilator beds	29/29 (19-40)	31/30 (19-42)	32/32 (20-46)

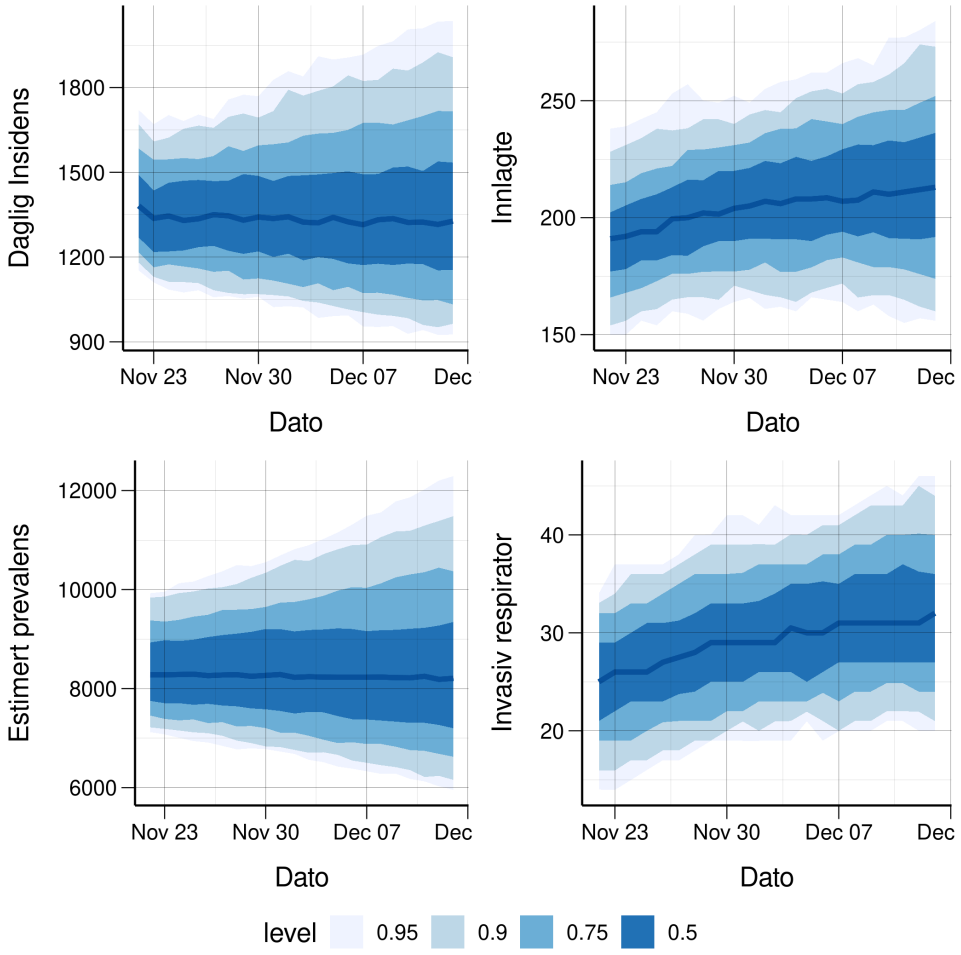
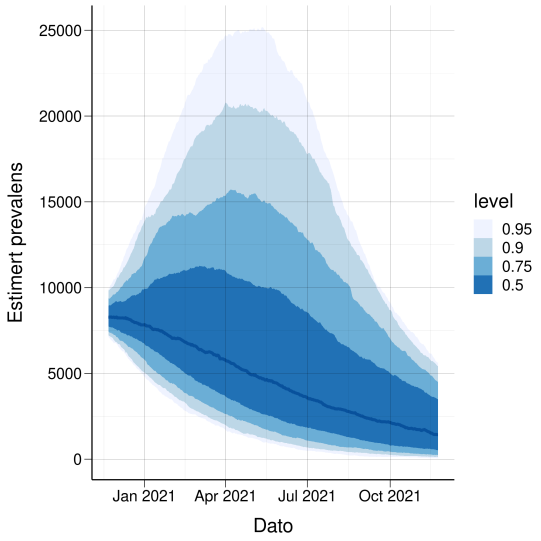


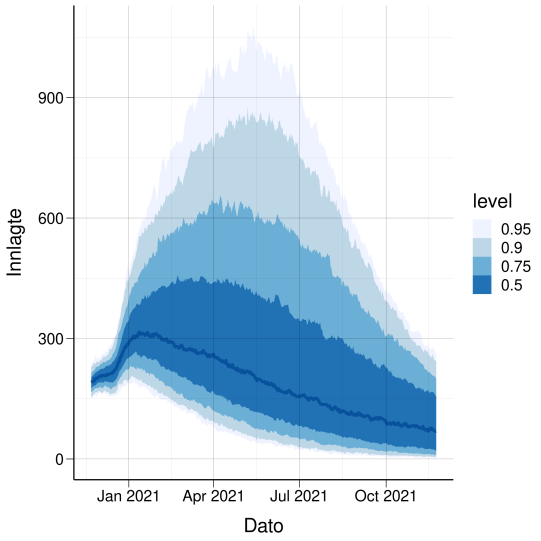
Figure 5: National 3 week predictions for incidence (top left),prevalence (bottom left),hospital beds (top right) and ventilator beds (bottom right)

4 National long-term predictions: Prevalence, Hospital beds and Ventilator beds

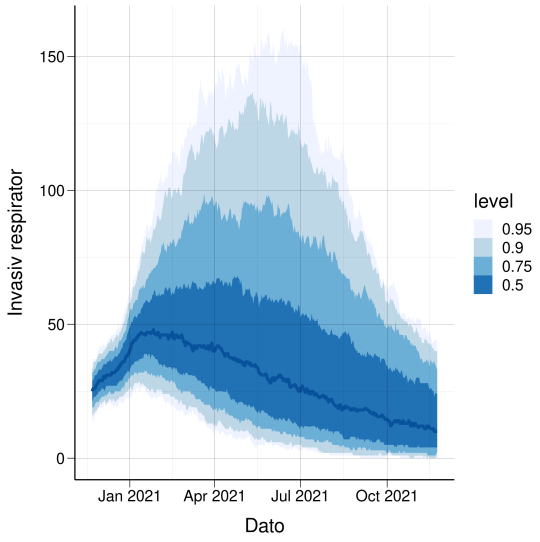
Results from 12-month forecasting of the calibrated national changepoint model, showing expected prevalence (Figure 6a), hospital beds (Figure 6b) and ventilator beds (Figure 6c). The figures are made using the 200 candidate models, where the reproductive numbers are varying according to their estimated uncertainty as of today. The confidence intervals shown in the plots are two-tailed around the median, and therefore the upper 95 % level shows the 97.5 % boundary. Note that age-specific attack rate after 21 days of projection is assumed to follow the demography in each county, instead of being informed by the current age-distribution of the laboratory-confirmed cases.



(a)



(b)



(c)

Figure 6: Long-term predictions for prevalence (a),hospital beds (b) and ventilator beds (c)

None of the simulations exceeded a surge capacity of **500 ICU** ventilator beds

5 National scenario-based long-term predictions: Hospital beds and Ventilator beds

Here we show how the epidemic estimated from the national changepoint model will develop under three assumed epidemiological scenarios, by fixing the effective reproduction number to be $1.1, 1.2$ or 1.3, from today. We show the daily number of COVID-19 patients in hospital, including patients receiving ventilator treatment, (Figure 7, and the daily number of patients on ventilator treatment, figure 8. Note that age-specific attack rate after 21 days of projection is assumed to follow the demography in each county, instead of being informed by the current age-distribution of the laboratory-confirmed cases. Additional information about the total attack rate (cumulative incidence) and healthcare burden and surge capacity for these scenarios are provided in Table 4.

Table 4: Predicted numbers of total infected, total number of hospitalisations, total number needing ventilator treatment, and the predicted peak number in ward (not in respirator), hospitalised (both with and without ventilator treatment) and ventilated treatments based on three different scenarios with R effective equal to 1.1, 1.2 and 1.3.

	Reff=1.1	**Reff=1.2**	**Reff=1.3**
Total:			
Attack rate (infected)	973.000(948.000 - 997.000)	1.650.000(1.640.000 - 1.670.000)	2.240.000(2.230.000 - 2.250.000)
Hospitalisations	29.800(28.900 - 30.500)	51.300(50.600 - 51.900)	69.600(69.100 - 70.200)
Patients on ventilator	2.380(2.280 - 2.490)	4.020(3.910 - 4.130)	5.400 (5.290 - 5.530)
At peak			
Hospital beds, excl. vent.	686(622 - 739)	1.880(1.810 - 1.950)	3.650(3.560 - 3.740)
Hospital beds, incl. vent.	801(725 - 860)	2.200(2.110 - 2.290)	4.260(4.170 - 4.380)
Ventilator beds	128(113 - 145)	338(314 - 365)	644(609 - 679)

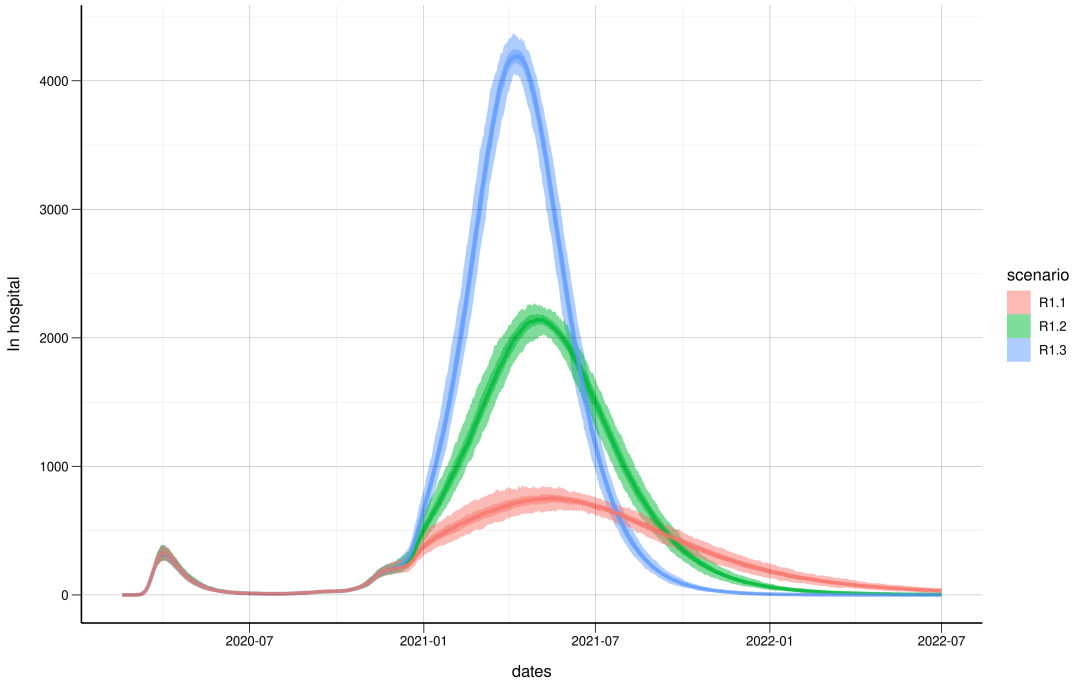


Figure 7: Predicted number of COVID-19 patients in hospital based on three different scenarios with R effective equal to 1.1, 1.2 and 1.3. Shaded areas show interquartile range and 95% confidence interval around the median.

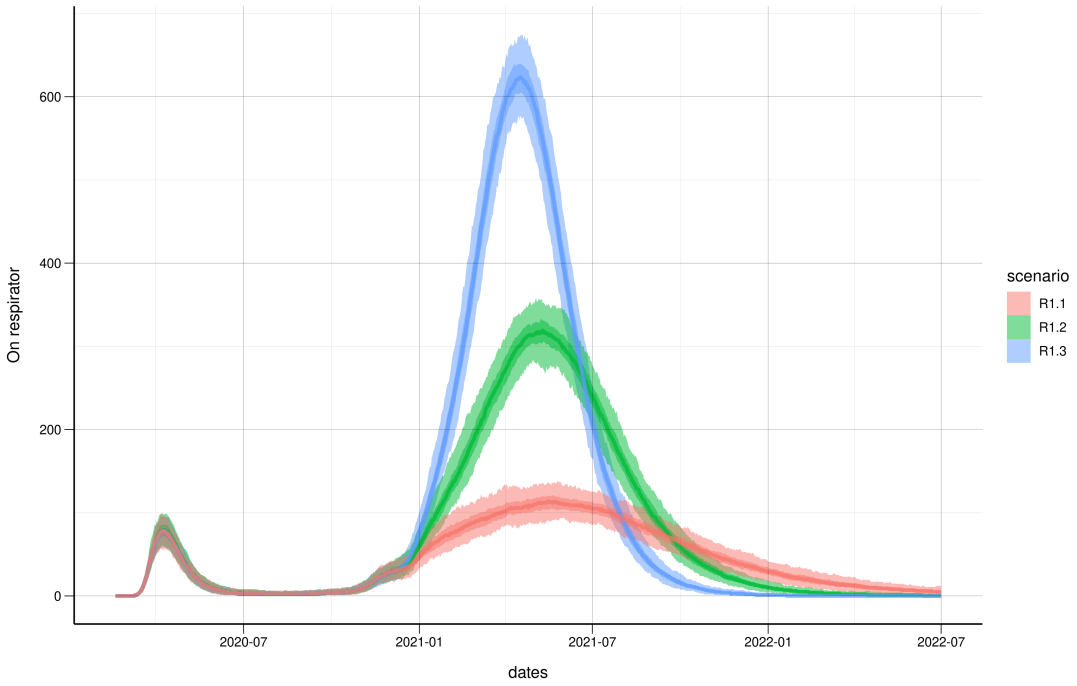


Figure 8: Predicted number of COVID-19 patients needing ventilator treatment based on three different scenarios with R effective equal to 1.1, 1.2 and 1.3. Shaded areas show interquartile range and 95% confidence interval around the median.

6 Estimated regional reproduction numbers

Calibration of our regional changepoint model to hospitalisation incidence data and test data leads to the following estimates for current regional reproduction numbers by county (Table 5). A full list of all regional reproduction numbers can be found at the end of the report.
Below we show the estimated daily number of COVID-19 patients admitted to hospital and the estimated daily number of laboratory-confirmed SARS-CoV-2 cases for each county. Model estimates are shown with blue medians and interquantile bands, which are compared to the actual true data, provided in red. The blue bands describe the uncertainty in the calibrated parameters, in addition to the stochastic elements of our model. Last four data points are shown in black as they may be affected by reporting delay.

Table 5: Estimated current regional reproduction numbers

Mean (95% CI)	Parameter	County	From	Pr(R>1)
1.27 (0.99-1.68)	R5	Oslo	2020-10-26	0.97
0.9 (0.34-1.46)	R4	Rogaland	2020-10-26	0.37
0.65 (0.09-1.39)	R4	Møre og Romsdal	2020-10-26	0.15
0.69 (0.05-1.62)	R4	Nordland	2020-10-26	0.22
1.34 (1.08-1.56)	R5	Viken	2020-10-26	1
1.38 (0.32-2.03)	R4	Innlandet	2020-10-26	0.82
0.88 (0.21-1.45)	R4	Vestfold og Telemark	2020-10-26	0.35
1.14 (0.35-1.87)	R4	Agder	2020-10-26	0.64
1 (0.28-2)	R5	Vestland	2020-10-26	0.44
0.97 (0.28-1.71)	R4	Trøndelag	2020-10-26	0.45
0.86 (0.11-1.86)	R4	Troms og Finnmark	2020-10-26	0.35

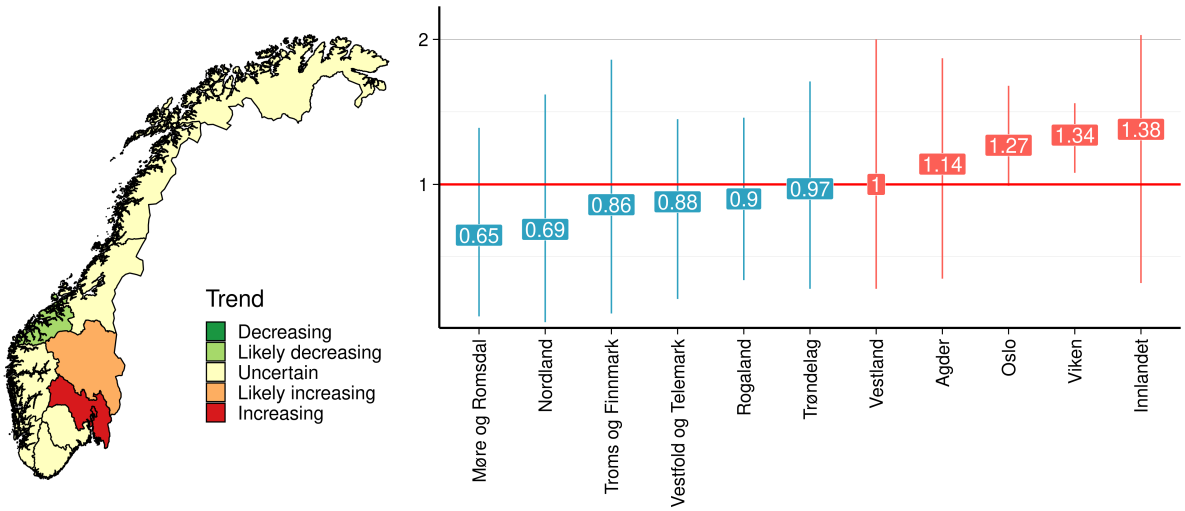
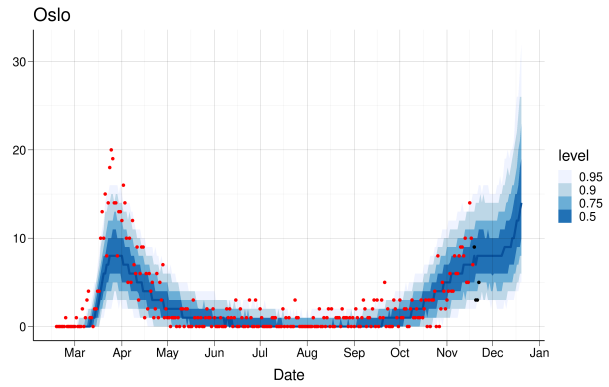
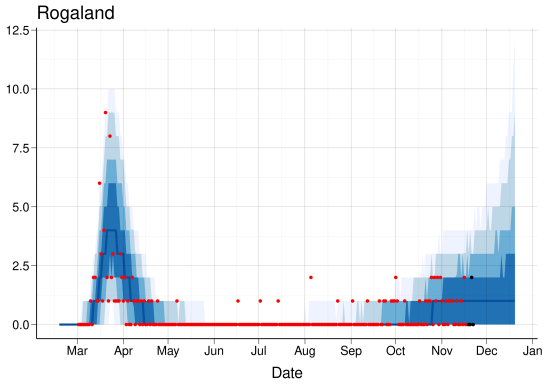
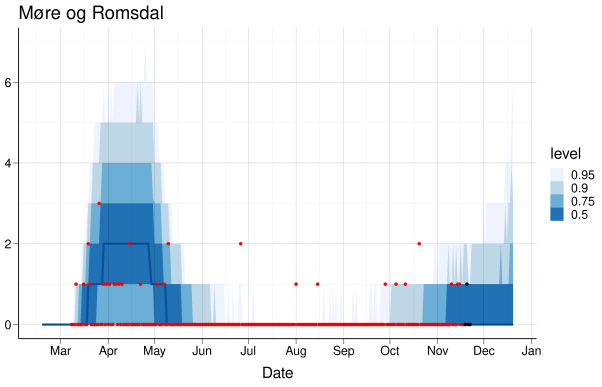


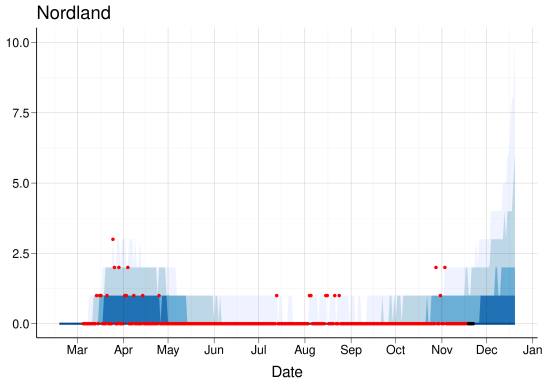
Figure 9: The map shows the direction of the trend in incidence in the counties based on the latest reproduction numbers shown in the other chart. The trend is increasing if the probability that the latest reproduction number is above one is above 95%, the trend is likely increasing if this probability is between 80% and 95%, the trend is uncertain if the probability is between 20% and 80%, the trend is likely decreasing if the probability is between 5% and 20% and is decreasing if the probability that the latest R is above one is less than 5%.

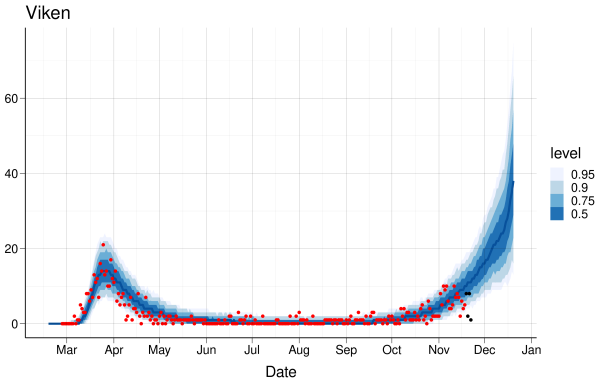
Estimated vs observed hospital incidence data by county:

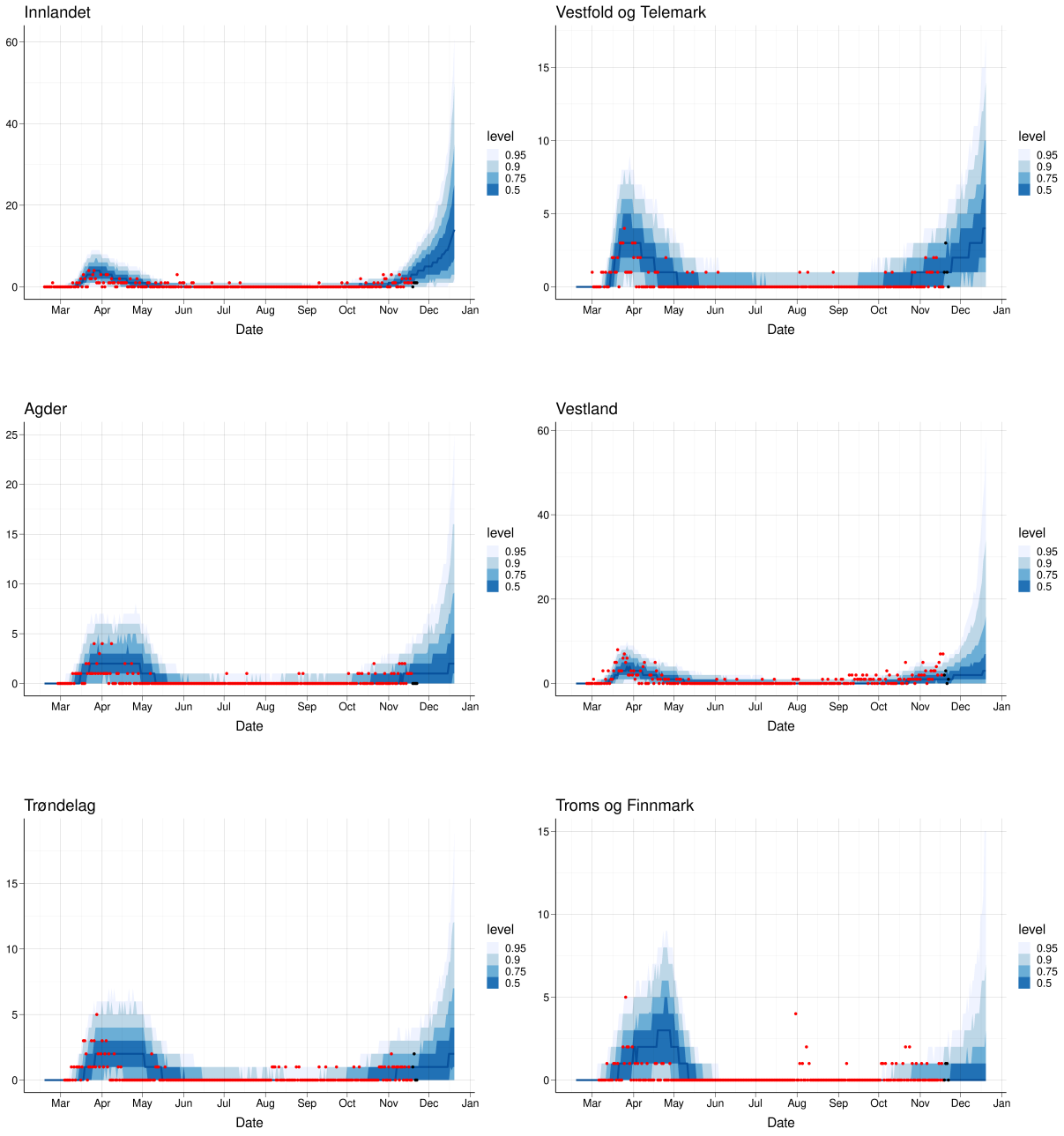




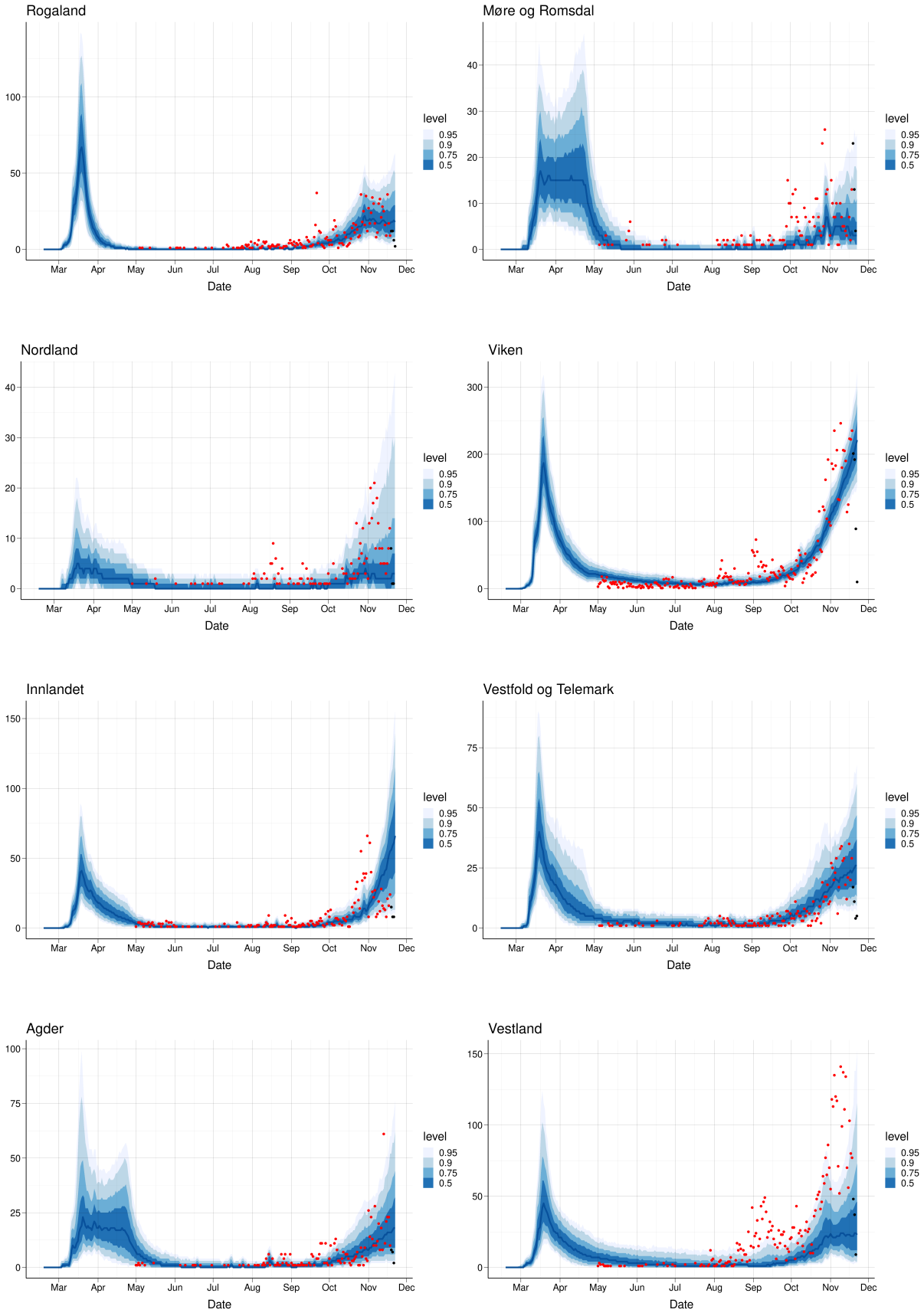








Estimated vs observed lab-confirmed test data by county:


Rogaland
Møre og Romsdal
Nordland
Viken
Innlandet
Vestfold og Telemark
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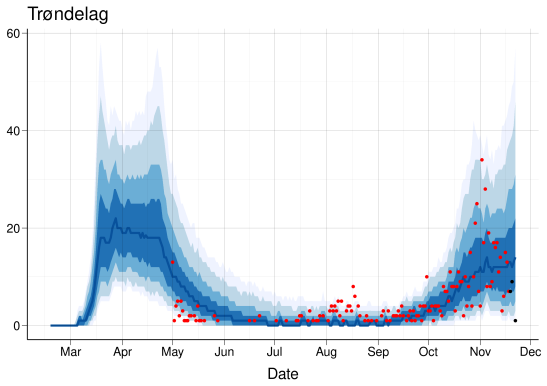
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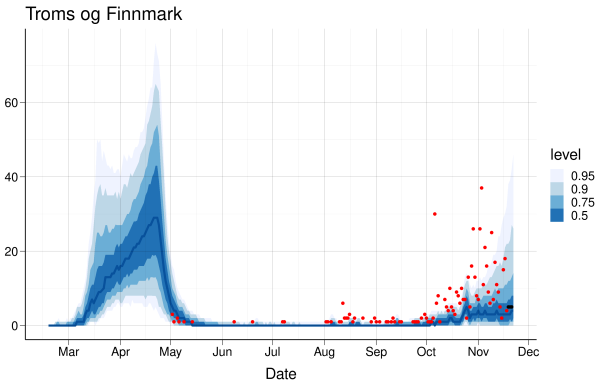
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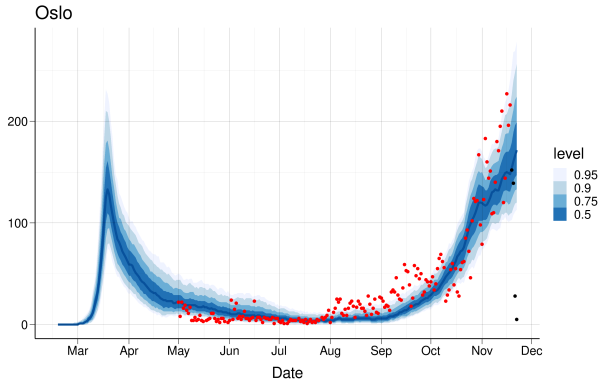
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0.5

7 Regional 3-week predictions: Cumulative (total) incidence and Prevalence

Below is shown the estimated short-term forecasting of total incidence of infected individuals (table 6), daily incidence (table 7) and prevalence (table 8) for each county.

Table 6: Estimated cumulative number of infections, 2020-11-22

Region	Total	Symptomatic	No. confirmed	Fraction reported	Min. fraction
Agder	5667 (3077; 8942)	3525 (1980; 5485)	992	18%	11%
Innlandet	7558 (3936; 11185)	4618 (2559; 6722)	1572	21%	14%
Møre og Romsdal	3315 (1819; 5602)	2131 (1230; 3548)	612	18%	11%
Nordland	1404 (665; 3651)	909 (459; 2233)	508	36%	14%
Oslo	31631 (22194; 40148)	18720 (13189; 23652)	9770	31%	24%
Rogaland	5817 (3140; 9144)	3738 (2124; 5734)	1492	26%	16%
Troms og Finnmark	3741 (1853; 6375)	2339 (1192; 3930)	827	22%	13%
Trøndelag	5871 (3315; 9480)	3666 (2140; 5791)	1183	20%	12%
Vestfold og Telemark	6658 (4780; 9011)	4176 (3041; 5541)	1100	17%	12%
Vestland	8591 (4594; 14733)	5351 (2930; 9000)	4874	57%	33%
Viken	35005 (27459; 42399)	21458 (17098; 25817)	9457	27%	22%

Fraction reported=Number confirmed/number predicted; Minimal fraction reported=number confirmed/upper CI

Table 7: Predicted incidence per day: Median/Mean (CI)

Region	1 week prediction (29 Nov)	2 weeks prediction (06 Dec)	3 weeks prediction (13 Dec)
Agder	64/94 (8-346)	74/125 (7-558)	87/172 (6-903)
Innlandet	286/306 (49-735)	377/432 (48-1191)	492/604 (52-1863)
Møre og Romsdal	18/26 (4-99)	14/25 (2-130)	13/28 (1-161)
Nordland	13/27 (3-141)	11/31 (1-216)	10/40 (0-318)
Oslo	448/459 (257-721)	554/567 (270-972)	672/703 (306-1337)
Rogaland	67/86 (16-261)	63/92 (11-335)	63/106 (9-426)
Troms og Finnmark	14/33 (2-190)	14/49 (1-306)	14/76 (1-492)
Trøndelag	73/88 (14-261)	76/106 (7-400)	80/135 (6-650)
Vestfold og Telemark	121/134 (34-320)	133/157 (33-427)	157/193 (41-560)
Vestland	105/162 (27-657)	106/217 (14-1159)	106/312 (13-2000)
Viken	1008/1011 (552-1528)	1215/1243 (573-2015)	1474/1515 (613-2650)

Table 8: Predicted prevalence. Number of infectious individuals (asymptomatic plus pre-symptomatic plus symptomatic) per day. Median/Mean and 95 perc. CI for three weeks prediction.

Region	29 Nov	06 Dec	13 Dec	low CI, 13 Dec	high CI, 13 Dec
Agder	389.5/522	459/705	564/977	136	4526
Innlandet	1550.5/1640	2021/2247	2568/3039	435	8641
Møre og Romsdal	132/165	108/163	120/194	32	912
Nordland	103.5/168	80/183	73.5/230	17	1665
Oslo	2521/2555	3086/3183	3850/3994	1806	7241
Rogaland	438/529	423/567	440/655	98	2470
Troms og Finnmark	93/182	89/257	99/399	25	2529
Trøndelag	444/520	486/626	559/806	110	3264
Vestfold og Telemark	715/780	762.5/880	914.5/1096	266	3057
Vestland	671.5/920	666.5/1185	695.5/1658	154	9455
Viken	5675.5/5708	6902/7004	8290/8506	3610	14441

8 Regional 3-week predictions: Hospital beds and ventilator beds

Below is shown the estimated short-term forecasting of expected hospital prevalence (table 9) and patients on ventilator treatment for each county (table 10).

Table 9: Number of hospitalisation beds occupied by Covid-19 patients: Median/Mean (CI)

Region	1 week prediction (29 Nov)	2 weeks prediction (06 Dec)	3 weeks prediction (13 Dec)
Agder	7/9 (0-31)	9/12 (1-43)	10/15 (0-62)
Innlandet	30/31 (4-70)	40/42 (6-103)	52/58 (6-152)
Møre og Romsdal	2/3 (0-12)	2/4 (0-14)	2/4 (0-17)
Nordland	1/3 (0-14)	2/4 (0-20)	2/5 (0-27)
Oslo	60/62 (33-94)	63/64 (33-99)	68/70 (33-119)
Rogaland	8/10 (1-27)	9/11 (1-33)	9/12 (1-41)
Troms og Finnmark	1/3 (0-15)	2/4 (0-23)	2/6 (0-34)
Trøndelag	7/8 (1-26)	9/11 (1-33)	10/14 (1-47)
Vestfold og Telemark	14/15 (3-35)	17/18 (4-45)	19/23 (4-60)
Vestland	13/15 (2-44)	15/20 (2-74)	16/27 (2-116)
Viken	94/94 (51-140)	124/125 (67-188)	158/159 (78-253)

Table 10: Number of ICU beds occupied by Covid-19 patients: Median/Mean (CI)

Region	1 week prediction (29 Nov)	2 weeks prediction (06 Dec)	3 weeks prediction (13 Dec)
Agder	1/1 (0-4)	1/1 (0-5)	1/2 (0-7)
Innlandet	3/3 (0-8)	4/5 (0-12)	6/7 (0-17)
Møre og Romsdal	0/0 (0-2)	0/0 (0-2)	0/1 (0-3)
Nordland	0/0 (0-2)	0/0 (0-3)	0/1 (0-3)
Oslo	8/8 (3-15)	9/9 (3-16)	9/10 (3-18)
Rogaland	1/1 (0-5)	1/1 (0-5)	1/2 (0-6)
Troms og Finnmark	0/0 (0-2)	0/0 (0-3)	0/1 (0-4)
Trøndelag	1/1 (0-4)	1/1 (0-5)	1/2 (0-6)
Vestfold og Telemark	2/2 (0-5)	2/2 (0-6)	2/3 (0-8)
Vestland	2/2 (0-6)	2/3 (0-9)	2/3 (0-13)
Viken	11/11 (4-19)	14/15 (6-24)	19/19 (8-31)

9 Scenario-based short-term predictions for Oslo:

Oslo has experienced increasing infection levels in the last months. Rising case numbers can lead to less efficient contact tracing due to a lack of resources. This, in turn, can cause the reproductive number to increase.To explore the short-term consequences of a less effective contact tracing in Oslo, we compare projections of the regional changepoint model, where the current reproduction number in Oslo (R5=1.26) is increased to 1.30; 1.35 and 1.40 from today, respectively. In these scenarios we assume no change to the reproductive numbers in the other counties. Table 11 and Figure compares these projected scenarios with a projection of the current epidemiological situation in Oslo.

Table 11: 4 week predictions in Oslo: Prevalence and Incidence (mean/median(CI))

Scenario	Prevalence	Incidence
Current	4654/4645 (2220-7463)	798/798 (418-1215)
R=1.30	4943/4916 (2441-7661)	855/850 (454-1323)
R=1.35	5257/5291 (2684-8197)	919/928 (476-1413)
R=1.40	5651/5688 (3016-8731)	999/1008 (526-1489)

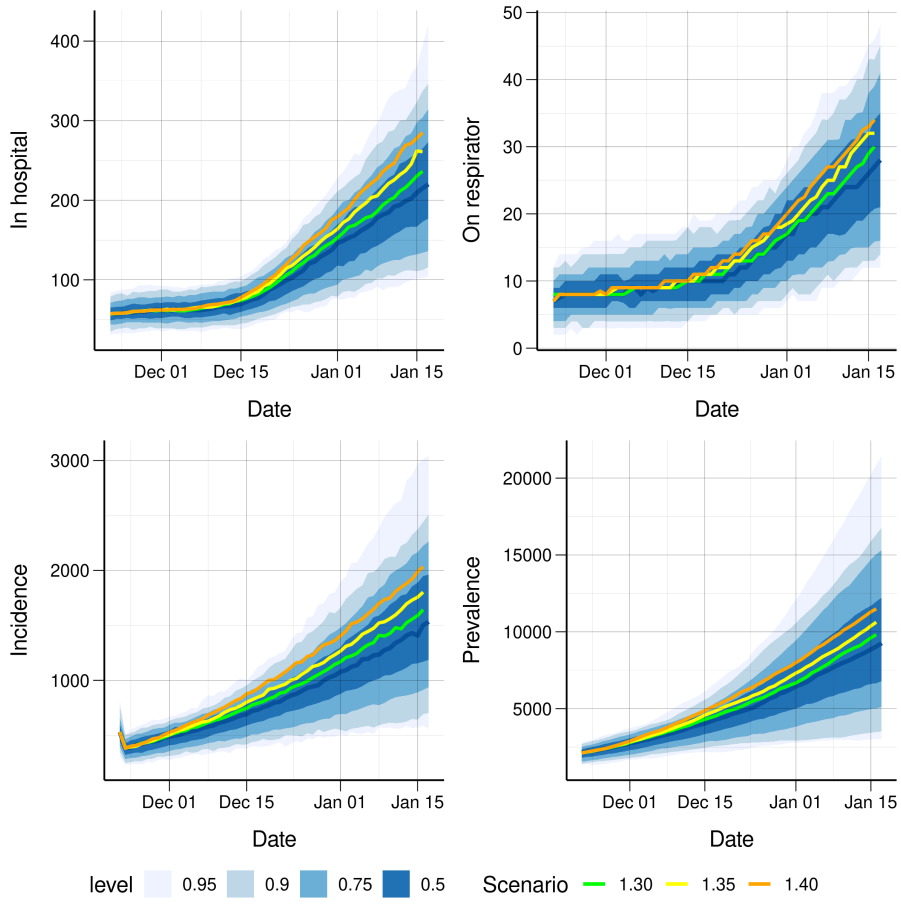


Figure 20: Future predictions for Oslo assuming the reproductive number will remain constant vs median of alternative scenarios. Confidence intervals correspond to "current scenario". Parameters showed are: Hospitalisations (top left), On respirator (top right),Incidence (bottom left) and Prevalence (bottom right).

10 Scenario-based short-term predictions for Bergen:

Similarly to the previous section, we explore the potential effect in Bergen municipality of an hypothetical increase in the reproduction number in Vestland. We compare projections of the regional changepoint model using the median reproduction number in Vestland (R5=0.95), with several scenarios (1.05,1.10,1.15) where the reproduction number is increased from today. As before, in these scenarios we assume no change to the reproductive numbers in the other counties. Table 12 and Figure compares these projected scenarios with a projection of the current epidemiological situation in Bergen.

Table 12: 4 week predictions in Bergen: Prevalence and Incidence (mean/median(CI))

Scenario	Prevalence	Incidence
Current	369/314 (168-965)	56/48 (20-139)
R=1.05	456/374 (195-1253)	73/61 (28-197)
R=1.10	508/416 (219-1378)	84/72 (33-224)
R=1.15	577/474 (230-1598)	95/79 (40-269)

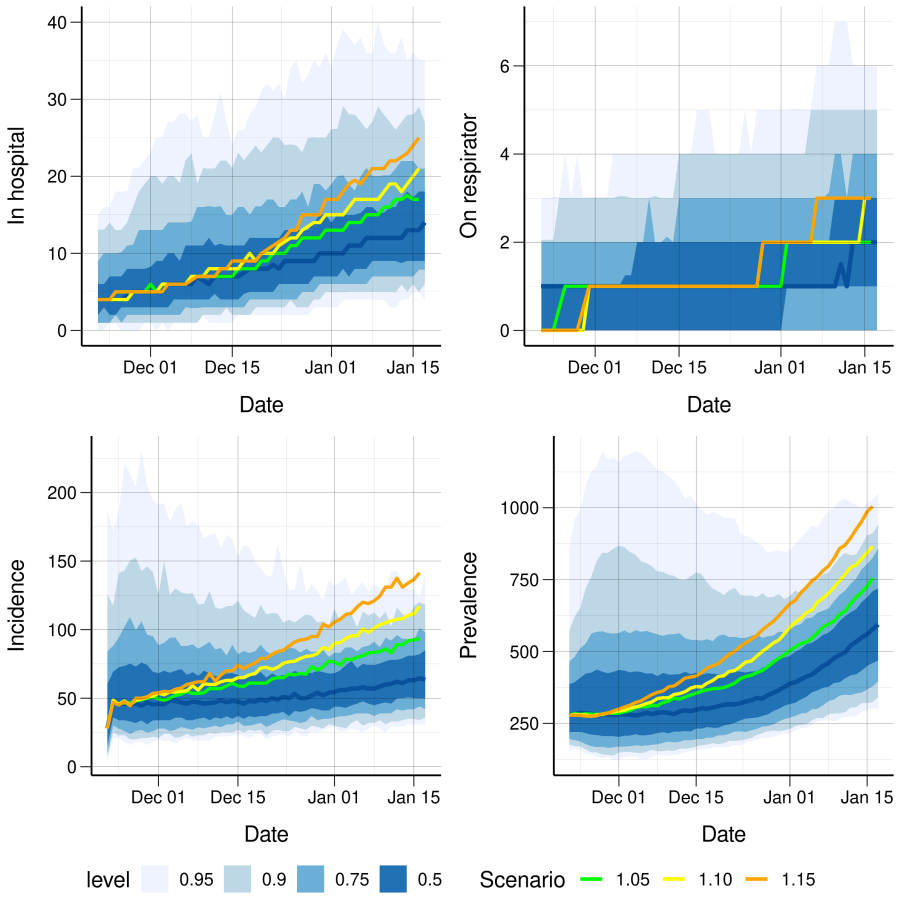
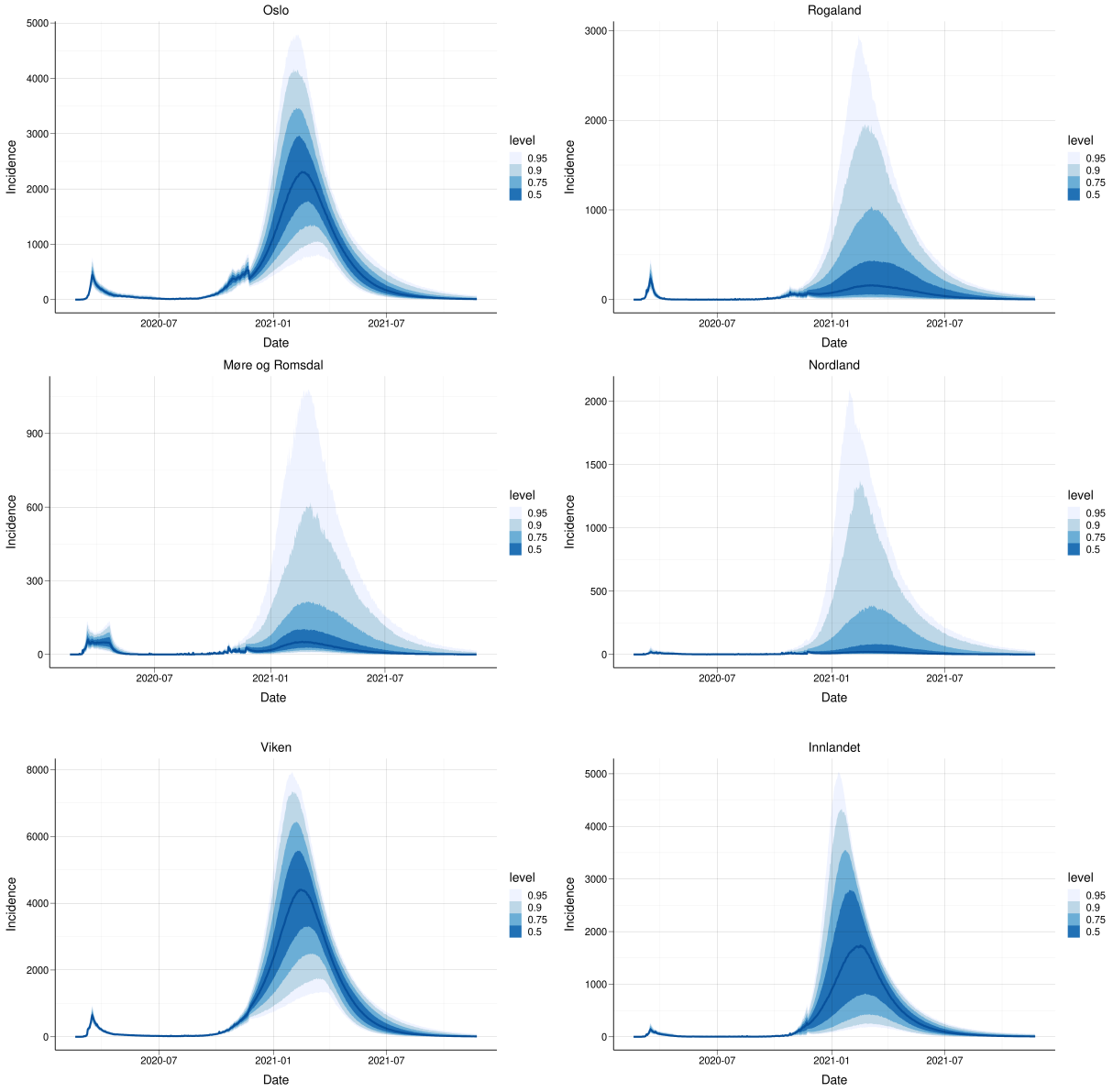


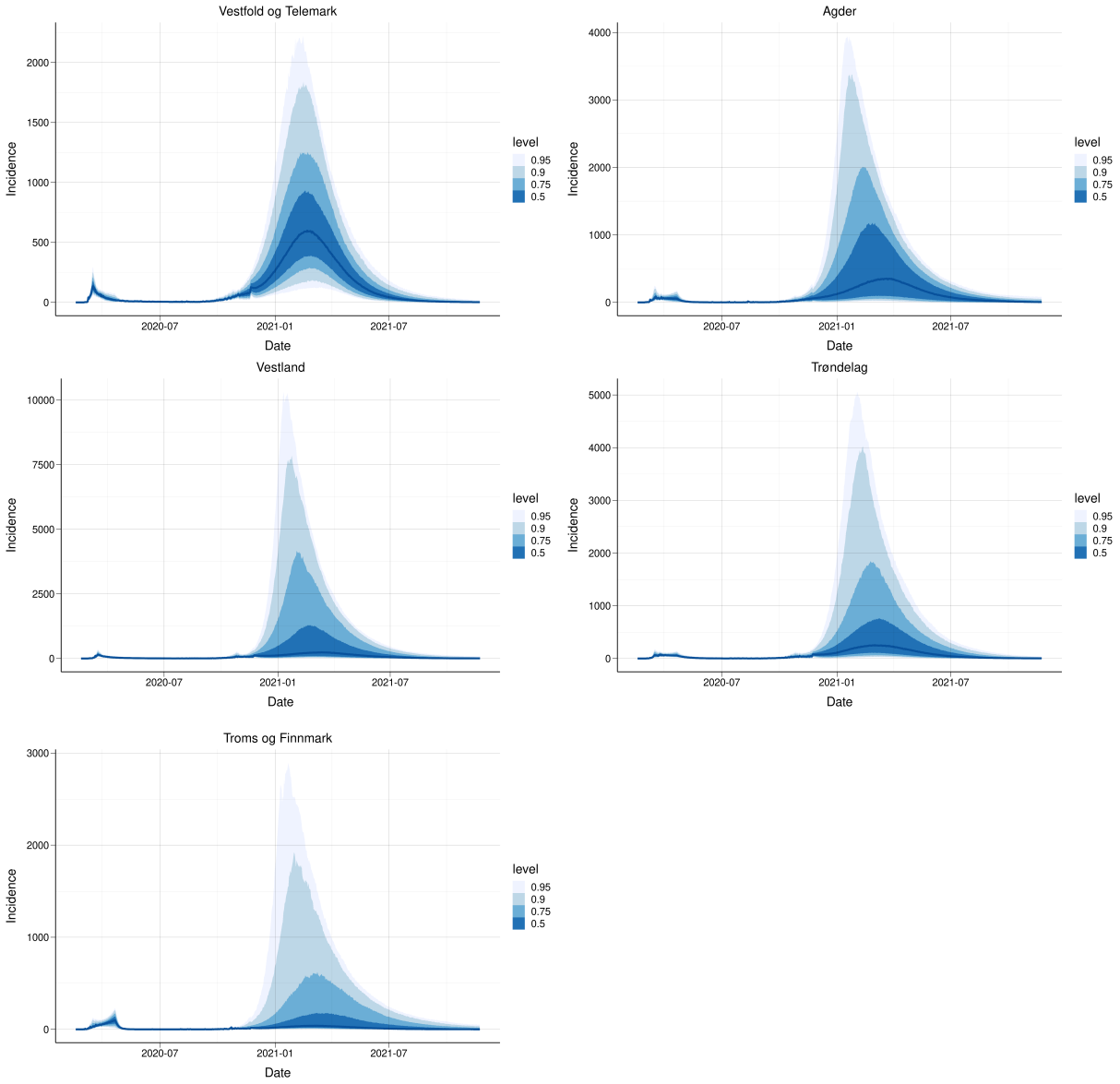
Figure 21: Future predictions for Bergen assuming the reproductive number will remain constant vs median of alternative scenarios. Confidence intervals correspond to "current scenario". Parameters showed are: Hospitalisations (top left), On respirator (top right),Incidence (bottom left) and Prevalence (bottom right).

11 Regional long-term predictions

11.1 Incidence

Predicted incidence (asymptomatic,pre-symptomatic and symptomatic) of the calibrated regional change-point model for each county per day, with confidence intervals.

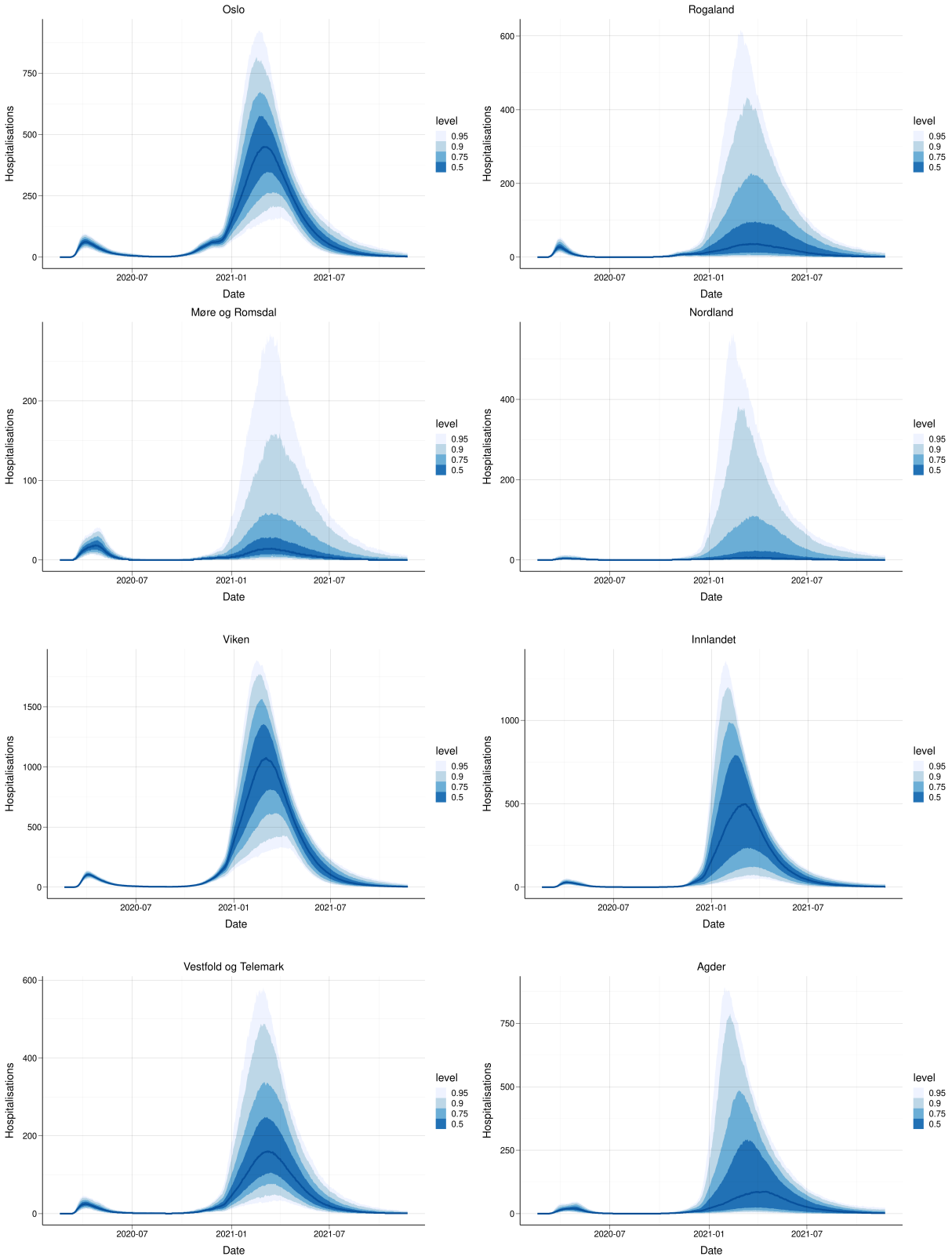




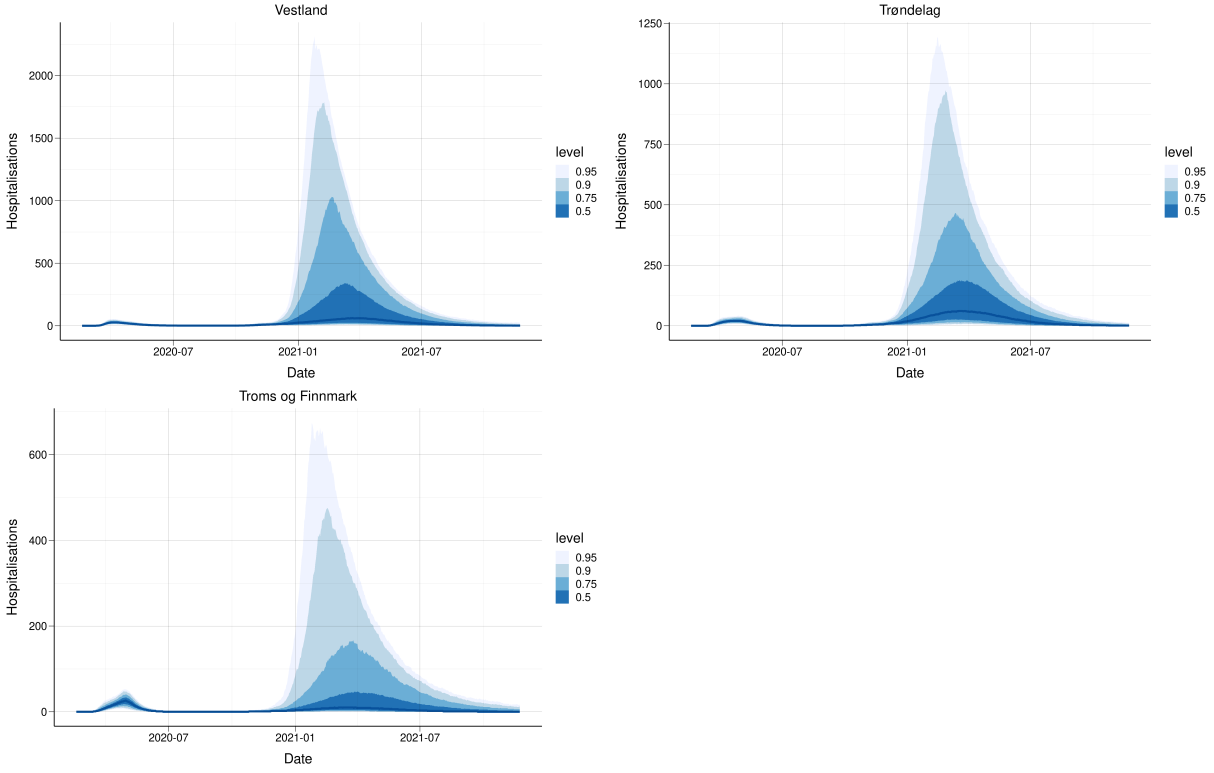
11.2 Hospitalisations

Estimated prevalence of COVID-19 patients in hospital, including patients receiving ventilator treatment.

11.2 Hospitalisations



11.2 Hospitalisations



12 Mobility data

Number of trips out from each municipality during each day is based on Telenor mobility data. We observed a large reduction in inter-municipality mobility in March (with minimum reached on Tuesday 17 March), and thereafter we see an increasing trend in the mobility lasting until vacation time in July. The changes in mobility in July coincides with the three-week "fellesferie" in Norway, and during August the mobility resumes approximately the same levels as pre-vacation time. There is however a significant local variation.

The reference level is set to 100 on March 2nd 2020 for all the figures in this section, and we plot the seven-day, moving average of the daily mobility. Figure 22 shows an overview of the mobility since March for the largest municipalities in each county, and Figure 23 shows the total mobility out from all municipalities in each county, including Oslo. Figure 24 and 25, zooms in on mobility from August 31, for municipalities and counties, respectively.

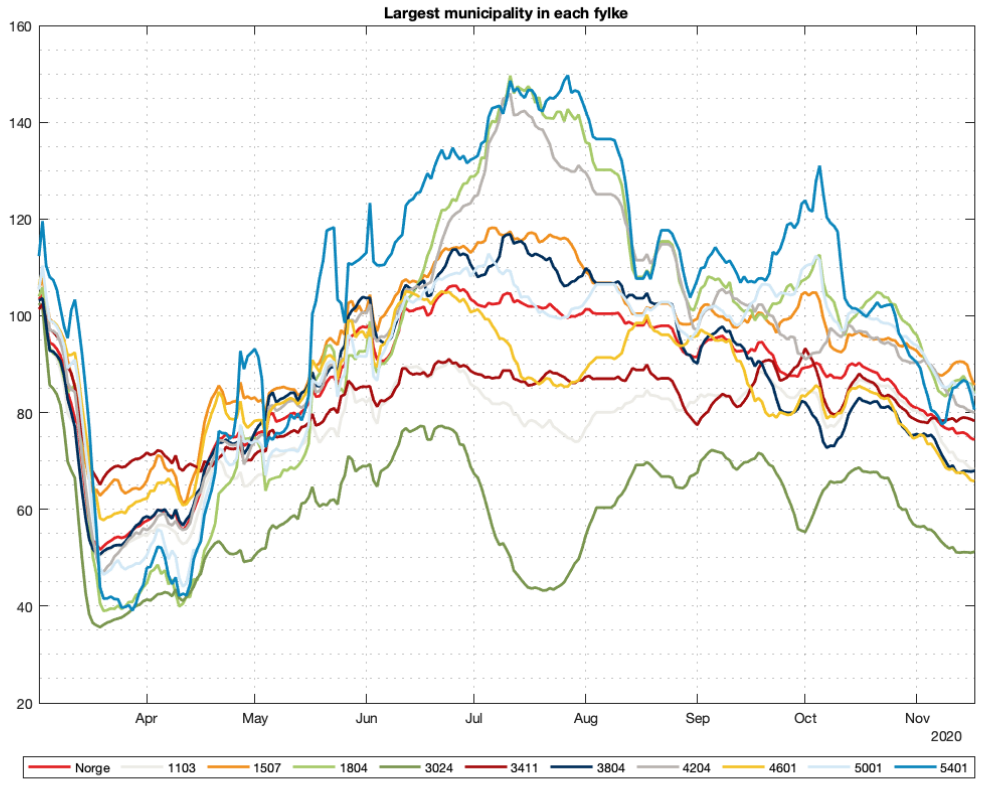


Figure 22: Mobility for selected municipalities for all of 2020: Nationally (Norge), Stavanger (1103), Ålesund (1507), Bodø (1804), Bærum (3024), Ringsaker (3411), Sandefjord (3804), Kristiansand (4204), Bergen (4601), Trondheim (5001), Tromsø (5401).

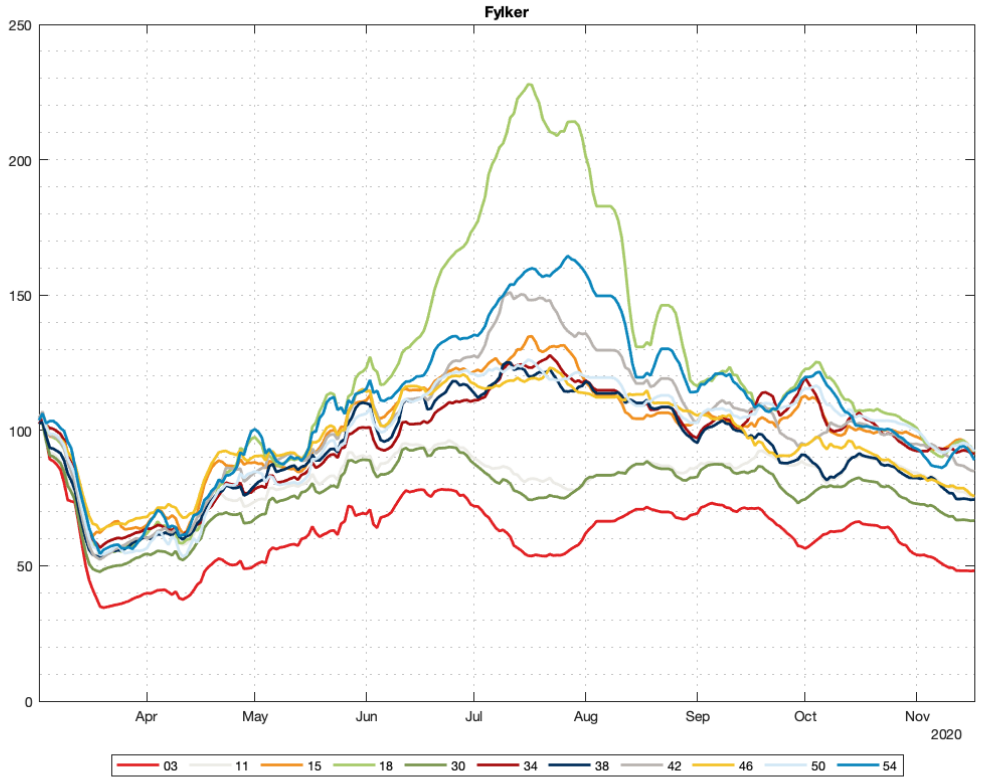


Figure 23: Mobility for fylker for all of 2020: Oslo (03), Rogaland (11), Møre og Romsdal (15), Nordland (18), Viken (30), Innlandet (34), Vestfold og Telemark (38), Agder (42), Vestland (46), Trøndelag (50), Troms og Finmark (54).

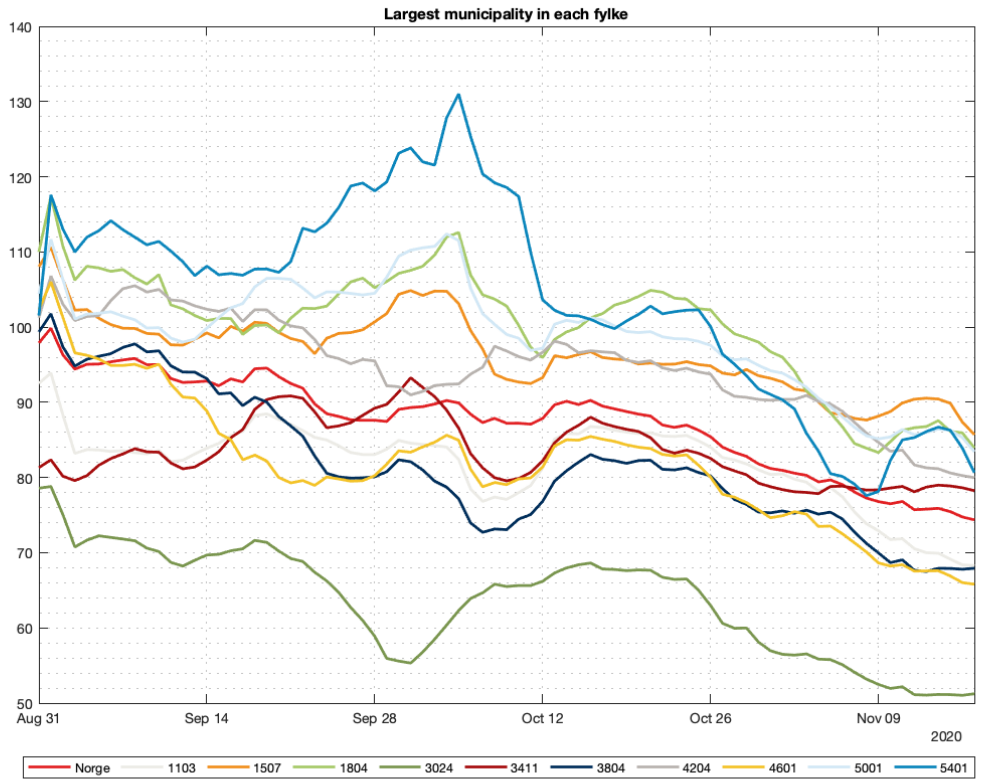


Figure 24: Zoom: Mobility from August 31 and onwards: Nationally (Norge), Stavanger (1103), Ålesund (1507), Bodø (1804), Bærum (3024), Ringsaker (3411), Sandefjord (3804), Kristiansand (4204), Bergen (4601), Trondheim (5001), Tromsø (5401).

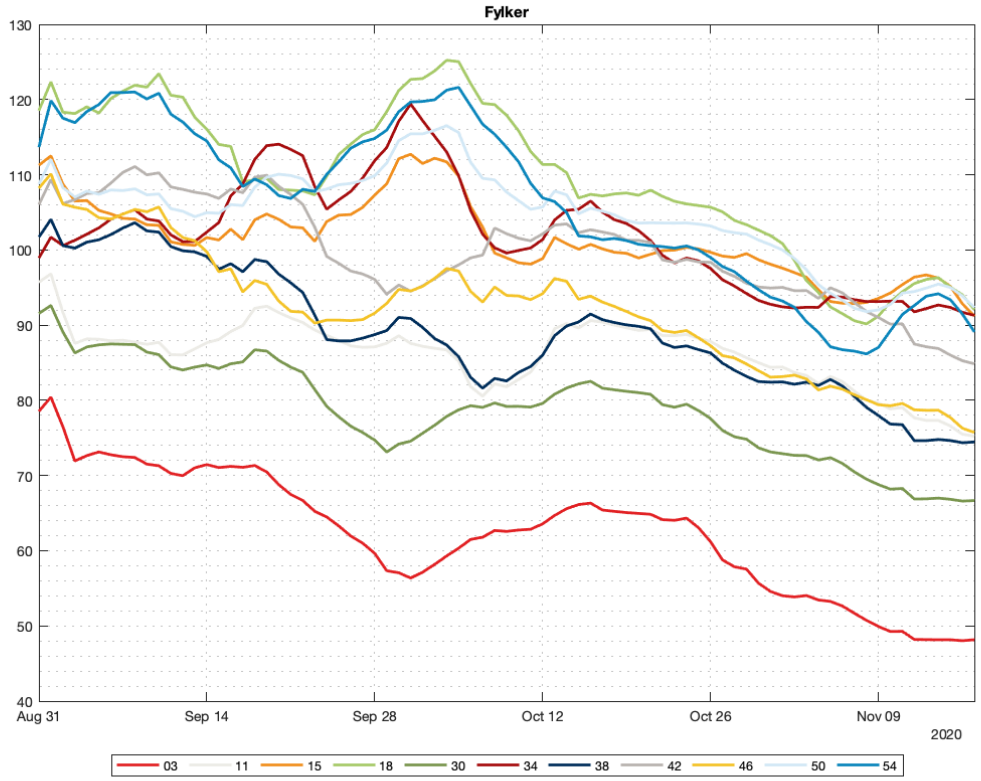


Figure 25: Zoom: Mobility from August 31 and onwards, per fylker: Oslo (03), Rogaland (11), Møre og Romsdal (15), Nordland (18), Viken (30), Innlandet (34), Vestfold og Telemark (38), Agder (42), Vestland (46), Trøndelag (50), Troms og Finnmark (54).

	44	45	46	47	48
Norge	85.4	80.6	76.8	74.8	67.9
Stavanger	84.0	79.8	72.9	68.4	61.4
Ålesund	94.8	91.8	88.2	87.4	74.5
Bodø	102.3	94.1	83.3	85.9	75.7
Bærum	63.0	56.4	52.5	51.0	46.6
Ringsaker	82.5	78.1	78.3	78.6	74.3
Sandefjord	80.2	75.2	70.0	67.8	60.9
Kristiansand	93.8	90.4	84.7	80.2	73.3
Bergen	80.0	75.5	68.6	66.0	62.1
Trondheim	97.6	93.0	85.1	85.3	74.6
Tromsø	100.1	89.1	78.2	83.9	78.5

Table 13: Municipalities

	44	45	46	47	48
Oslo	61.2	53.9	49.9	48.0	43.5
Rogaland	87.8	83.7	79.6	75.5	67.4
Møre og Romsdal	99.7	97.0	93.5	92.8	78.0
Nordland	105.7	98.6	91.2	94.0	81.4
Viken	77.6	72.7	68.8	66.6	61.2
Innlandet	97.5	92.3	93.1	91.7	86.2
Vestfold og Telemark	86.3	82.1	78.0	74.4	68.7
Agder	98.4	94.6	91.0	85.3	78.2
Vestlandet	87.3	83.3	79.4	76.3	70.5
Trøndelag	103.2	98.9	92.0	93.9	81.0
Troms og Finnmark	99.0	92.4	87.0	91.5	82.0

Table 14: Counties

Mobility for Norway and selected municipalities is displayed in Tables 13 and mobility for counties is displayed in 14. The percentages in the tables are to be interpreted towards the reference level of 100% for week 10 in March 2020. The color-coding encodes the following: 'Green' monotonic decrease in mobility, 'Yellow' almost monotonic decrease or flat mobility trend, 'Red' increasing mobility.

12.1 Foreign roamers on Telenor's network in Norway

An analysis of foreign roamers in Norway for 2020 has been carried out, to better understand the potential virus importation. In Figure 26 the total number of roamers per day per county are displayed. We can see an approximate 40% drop in the number of visiting roamers after the lock-down in March. The number of visiting roamers recover during the Summer, and there is a spike of visitors in August followed by a drop again. During October the levels of visiting, foreign roamers to Norway have reached quite high levels, just 10% short of the all-year high, and Oslo and Viken have seen big increases in visitors. The level seems to have stabilised.

Figure 27 showcases the levels of roamers from four different countries: Poland, Denmark, Lithuania and Germany, and the figure illustrates where in Norway the roamers of the given nationality are staying in each day. For example, the Polish roamers are typically going to the cities, Oslo, Bergen, Trondheim, and Stavanger, and they show quite high visiting levels during all of 2020. The visiting-levels in October are all-time highs for 2020. In comparison, thefre are many Danish roamers early in 2020, and levels drop after the lock-down, with a visiting spike during July followed by a drop after Summer. German roamers show the same behaviour, but at lower, absolute levels. Lithuanian visitors show a similar patterns as the Polish visitors.

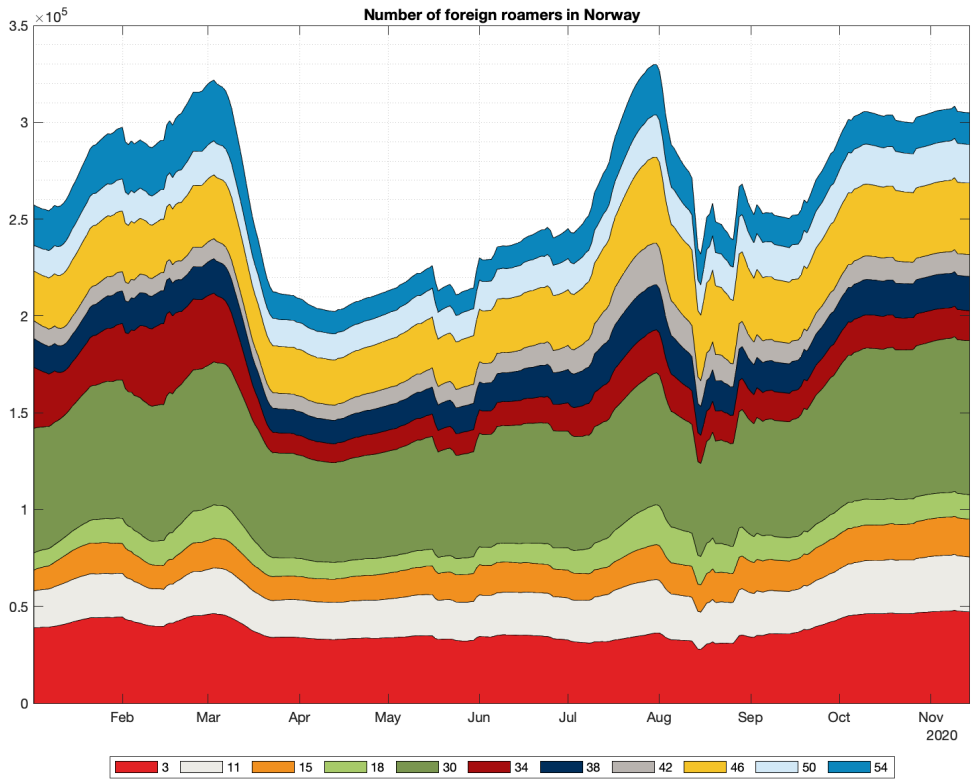


Figure 26: The total number of foreign roamers in Norway broken down on different fylker: Oslo (3), Rogaland (11), Møre og Romsdal (15), Nordland (18), Viken (30), Innlandet (34), Vestfold og Telemark (38), Agder (42), Vestland (46), Trøndelag (50), Troms og Finmark (54).

12.1 Foreign roamers on Telenor's network in Norway

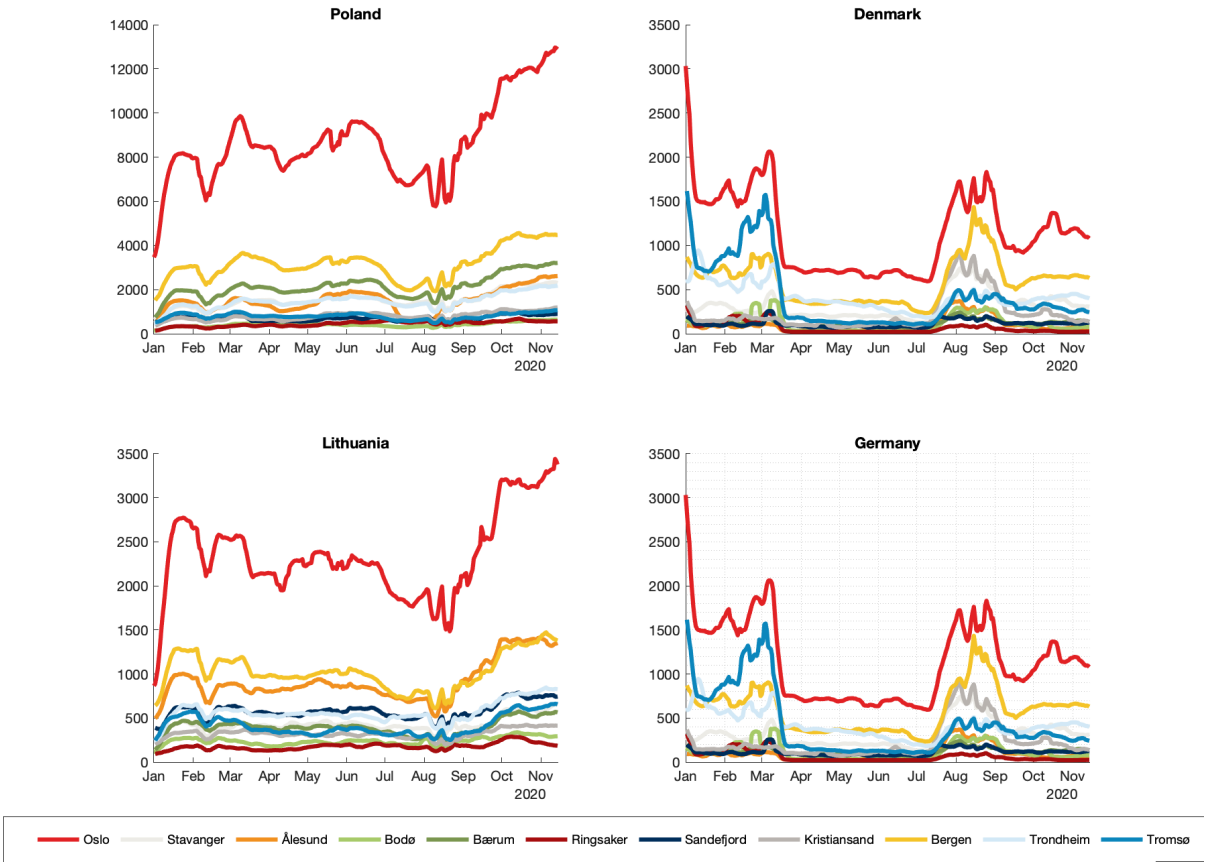


Figure 27: Roamers from Poland, Denmark, Lithuania and Germany, broken down on the the largest municipalities in each fylke.

13 Methods

Details on this model can be found here https://www.fhi.no/sv/smittsomme-sykdommer/corona/koronavirus-modellering/. We use assumptions related to hospitalisation stay based on Norwegian data–NPR data linked with MSIS data. The parameters are specified in the report 2020.05.19 Corona report.pdf.
Estimation of the reproduction numbers (and of the amplification factor in seeding of the epidemic at the start) is done using Approximate Bayesian Computation (ABC), as described in Engebretsen et al. (2020): https://royalsocietypublishing.org/doi/10.1098/rsif.2019.0809.
Briefly: We run a sequential Monte Carlo ABC in order to obtain 1000 parameter sets of the different reproduction number for each county, which best fit the hospitalisation data of each county. We also obtain the best estimate for the amplification factor F used to seed the epidemic. Next we run the model with these 1000 parameter sets again, from the beginning until today, plus three weeks into the future, or plus 12 months. Using these 1000 trajectories of the future, we make future predictions and confidence intervals. They account for the changes in the movement patterns between municipalities that have occurred since the start of the epidemic.

New in this report is the use of different number of reproduction numbers in each of the counties (5 in Oslo and Viken, and 4 in the rest). For some of the counties, it is difficult to estimate regionally varying parameters when the hospital incidence data is so low.

Model

We use a metapopulation model to simulate the spread of COVID-19 in Norway in space and time. The model consists of three layers: the population structure in each municipality, information about how people move between different municipalities, and local transmission within each municipality. In this way, the model can simulate the spread of COVID-19 within each municipality, and how the virus is transported around in Norway.

Transmission model

We use an SEIR (Susceptible-Exposed-Infected-Recovered) model without age structure to simulate the local transmission within each area. Mixing between individuals is assumed to be random. Demographic changes due to births, immigration, emigration and deaths are not considered. The model distinguishes between asymptomatic and symptomatic infection, and we consider presymptomatic infectiousness among those who develop symptomatic infection. In total, the model consists of 6 disease states: Susceptible (S), Exposed, infected, but not infectious (E), Presymptomatic infected (E2), Symptomatic infected (I), Asymptomatic infected (Ia), and Recovered, either immune or dead (R). A schematic overview of the model is shown in figure 28.

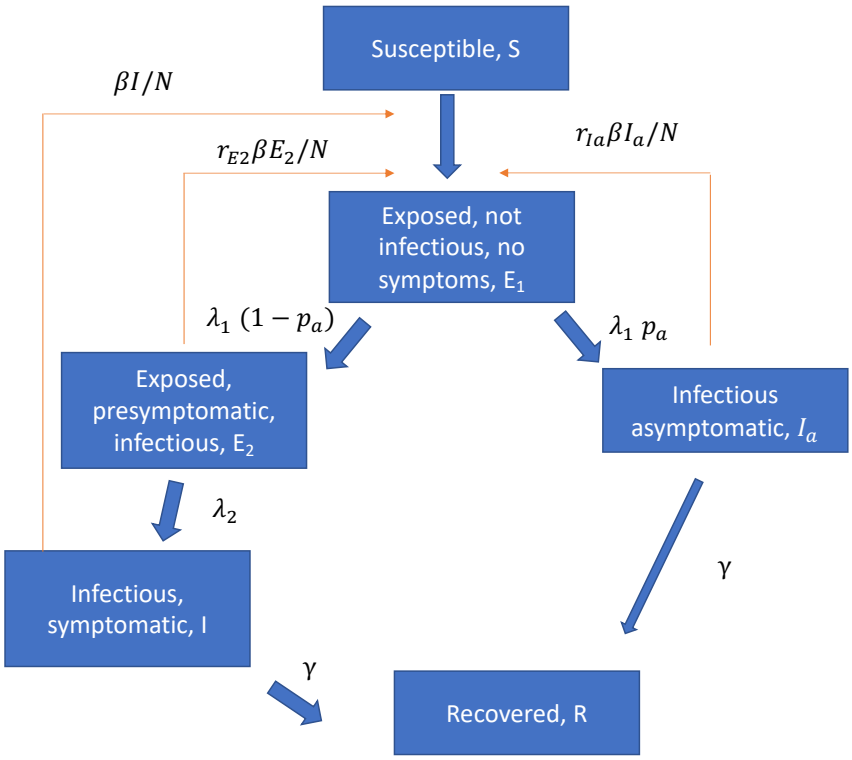


Figure 28: Schematic overview of the model.

Movements between municipalities:

We use 6-hourly mobility matrices from Telenor to capture the movements between municipalities. The matrices are scaled according to the overall Telenor market share in Norway, estimated to be 48%. Since week 8, we use the actual daily mobility matrices to simulate the past. In this way, alterations in the mobility pattern will be incorporated in our model predictions. To predict future movements, we use the latest weekday measured by Telenor. We follow closely the development in the mobility matrices, and weekend patterns will be introduced if necessary.

Healthcare utilisation

Based on the estimated daily incidence data from the model and the population age structure in each municipality, we calculated the hospitalisation using a weighted average. We correct these probabilities by a factor which represents the over or under representation of each age group among the lab confirmed positive cases. The hospitalisation is assumed to be delayed relative to the symptom onset. We calculate the number of patients admitted to ventilator treatment from the patients in hospital using age-adjusted probabilities and an assumed delay.

Seeding

At the start of each simulation, we locate 5.367.580 people in the municipalities of Norway according to data from SSB per January 1. 2020. All confirmed Norwegian imported cases with information about residence municipality and test dates are used to seed the model, using the data available until yesterday. For each case, we add an additional random number of infectious individuals, in the same area and on the same day, to account for asymptomatic imported cases who were not tested or otherwise missed. We denote this by the amplification factor.

Reproduction number, national changepoint model

We assume a first reproduction number R_0 until March 14, a second reproduction number R_1 until April 19, a third reproduction number R_2 until May 10, a fourth reproduction number R_3 until June 30, R_4 until July 31, R_5 until August 31, R_6 from September 1 until September 30, R_7 from October 1 until October 26,and an eighth reproduction number until today. This last reproduction number is used for the future. The changepoints follow the change in restrictions introduced. We estimate the reproduction numbers so that the predicted number of hospitalised individuals is closest to the true number of hospitalised individuals, from March 10 until the last available data point, and the simulated positive tests are closest to the data on laboratory-confirmed COVID-19 cases from May 1 until the latest available data point. We use a method called sequential ABC which tests millions of combinations of R_0, R_1, R_2, R_3, R_4, R_5, R_6, R_7,R_8 and the amplification factor, to determine the 200 ones that lead to the best fits to the hospitalisation incidence. The algorithm is described in Engebretsen et al. (2020) https://royalsocietypublishing.org/doi/10.1098/rsif.2019.0809.

Calibration to test data, national changepoint model

We include the laboratory-confirmed cases in the calibration procedure, as these contain additional information about the transmissibility, and the delay between transmission and testing is shorter than the delay between transmission and hospitalisation. Therefore, we simulate also the number of detected positive cases in our model. We assume that the number of detected positive cases can be modelled as a binomial process of the simulated daily total incidence of symptomatic and asymptomatic cases, with a success probability π_t, which changes every day. We also assume a delay d between the day of test and the day of transmission. In the ABC procedure we thus use two summary statistics, one is the distance between the simulated hospitalisation incidence and the observed incidence, and the other is the distance between the observed number of laboratory-confirmed cases and the simulated ones. As the two summary statistics are not of the same scale, we use two separate tolerances in the ABC-procedure, ensuring that we get a good fit to both data sources.

The data on the number of positive cases are more difficult to use, as the test criteria and capacity have changed multiple times. We take into account these changes by using the total number of tests performed on each day, as a good proxy of capacity and testing criteria. Moreover, we choose not to calibrate to the test data before May 1, because the test criteria and capacity were so different in the early period. The detection probability is modelled as

$$\pi_t = \exp\left(\pi_0 + \pi_1 \cdot k_t\right)/(1 + \exp(\pi_0 + \pi_1 \cdot k_t)),$$

where k_t is the number of tests actually performed on day t, and π_0 and π_1 are two parameters that we estimate, assuming positivity of π_1. We also estimate the delay d. We choose to use a 7-days backwards moving average for the covariate k_t, and to calculate the distance between the observed number of positive tests and the simulated ones using a 7-days backwards moving average. We do this to take into account potential day-of-the-week-effects. For example, it could well be that the testing criteria are different on weekends and weekdays. However, using instead the number of tests and calibrating on a daily basis would lead to a larger day-to-day variance. This is likely why we find that the uncertainty in the simulated positive cases seems somewhat too low, and that we do not capture all the variance in the daily test data. Moreover, the binomial assumption could be too simple, and a beta-binomial distribution would allow more variance. A limitation of our current model for the detection probability, is that we only capture the changes in the test criteria that are captured in the total number of tests performed.

Methods for the regional changepoint model

The method is exactly like the one of the national model, except that every county has its own reproduction numbers (and changepoints for these). We run the sequential Monte Carlo ABC in order to obtain 1000 parameter sets of the different reproduction number for each county, which best fit the hospitalisation data and the test data (7 days moving average) of each county. We also obtain the best estimate for

one amplification factor F used to seed the epidemic. Next we run the model with these 1000 parameter sets again, from the beginning until today, plus three weeks into the future (or for an additional year). Using these 1000 trajectories of the future, we make future predictions and confidence intervals.
We use of different number of reproduction numbers in each of the counties (5 in Oslo and Viken, and 4 in the rest). For some of the counties, it is difficult to estimate regionally varying parameters when the hospital incidence data is so low.

Parameters used today

Figures 29 and 30 indicate which assumptions we make in our model, related to hospitalisation. We obtained data from the Norwegian emergency registry BEREDT-C19. These estimates will be regularly updated, on the basis of new data.

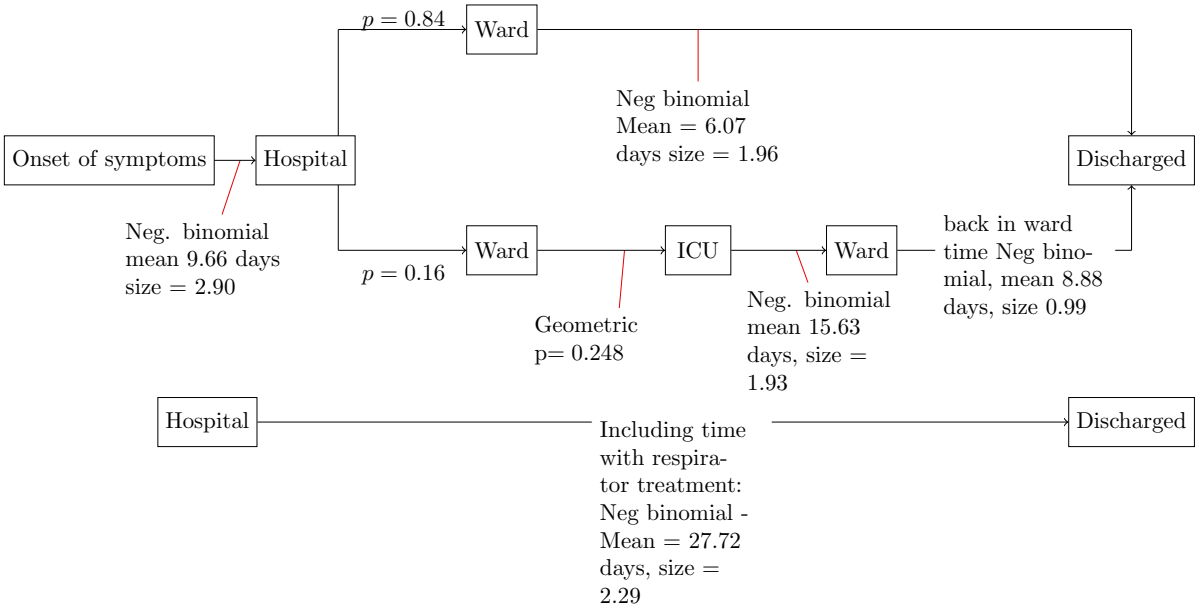


Figure 29: Hospital assumptions and parameters used before 1 August

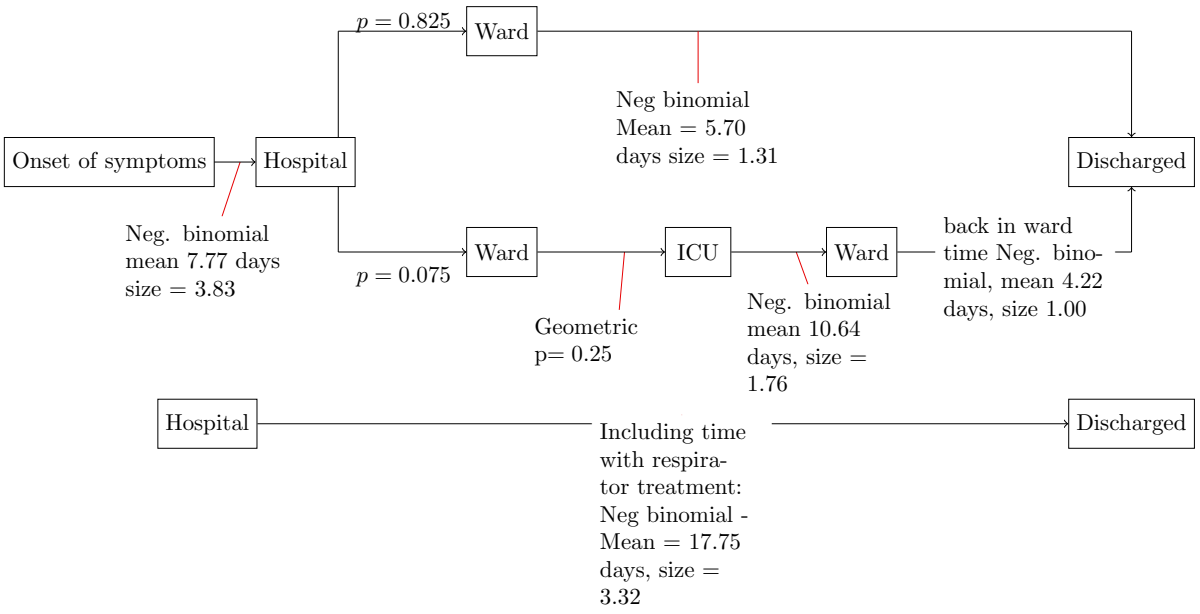


Figure 30: Hospital assumptions and parameters used after 1 August

Table 15: Estimated parameters

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	Period
R0s	2.234	3.055	3.304	3.336	3.597	4.618	Until March 14
R1s	0.327	0.425	0.45	0.451	0.477	0.547	From March 15 to April 19
R2s	0.385	0.711	0.829	0.822	0.913	1.228	From April 20 until May 10
R3s	0.32	0.747	0.86	0.835	0.93	1.213	From May 11 until June 30
R4s	0.147	0.676	0.835	0.836	1.005	1.539	From July 1 until July 31
R5s	0.776	0.996	1.083	1.081	1.17	1.345	From Aug 1 until Aug 31
R6s	0.782	0.885	0.933	0.929	0.975	1.14	From Sept 1 to Sept 30
R7s	0.961	1.171	1.251	1.258	1.344	1.537	From Oct 1 to Oct 25
R8s	0.991	1.241	1.383	1.366	1.481	1.752	From Oct 26 to Nov 4
R9s	0.913	0.982	1.013	1.019	1.056	1.216	From Nov 5
AMPs	1.278	2.28	2.705	2.69	3.11	4.362	From February
π_0	-2.3	-1.475	-1.123	-1.151	-0.853	-0.121	-
π_1	1.9e-06	3.7e-05	6.2e-05	6.2e-05	8.4e-05	1.6e-04	-
delays	0	0	1	1.41	3	4	-

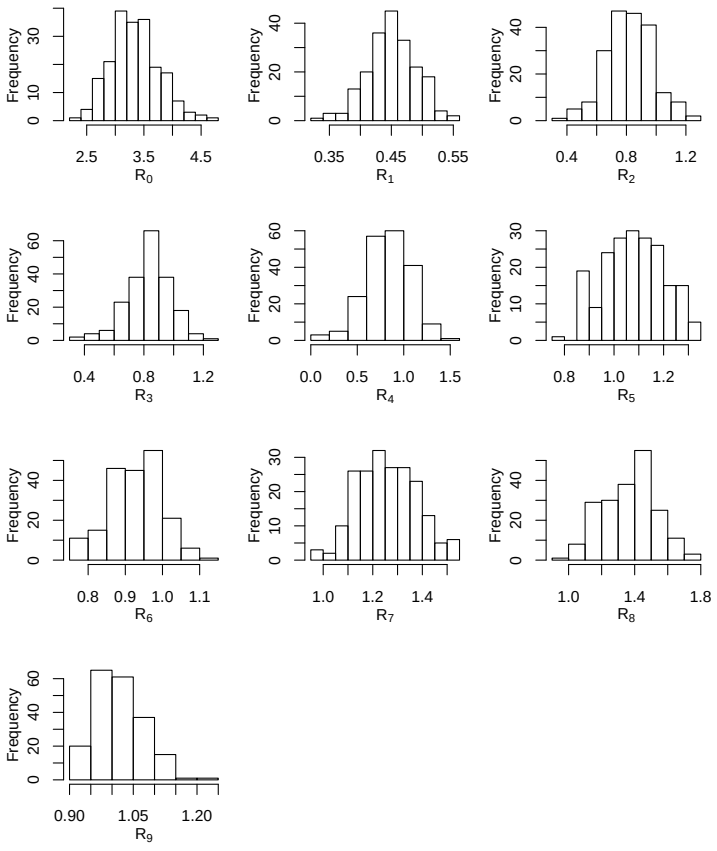


Figure 31: Estimated densities of the reproduction numbers. National model

Table 16

Mean (95% CI)	Parameter	County	From	To	Pr(R>1)
4.53 (3.4-5.71)	R0	Oslo	2020-02-17	2020-03-14	1
3.96 (2.73-5.06)	R0	Rogaland	2020-02-17	2020-03-14	1
3.94 (2.06-5.86)	R0	Møre og Romsdal	2020-02-17	2020-03-14	1
2.91 (0.81-5.38)	R0	Nordland	2020-02-17	2020-03-14	0.96
4.37 (3.08-5.44)	R0	Viken	2020-02-17	2020-03-14	1
3.98 (2.29-5.59)	R0	Innlandet	2020-02-17	2020-03-14	1
4.27 (2.32-6.07)	R0	Vestfold og Telemark	2020-02-17	2020-03-14	1
2.92 (1.13-5.14)	R0	Agder	2020-02-17	2020-03-14	0.98
3.5 (1.95-4.97)	R0	Vestland	2020-02-17	2020-03-14	1
4.23 (1.5-6.08)	R0	Trøndelag	2020-02-17	2020-03-14	1
2.47 (0.96-4.47)	R0	Troms og Finnmark	2020-02-17	2020-03-14	0.97
0.69 (0.44-0.95)	R1	Oslo	2020-03-15	2020-04-19	0.01
0.96 (0.68-1.26)	R2	Oslo	2020-04-20	2020-06-19	0.39
0.92 (0.58-1.32)	R3	Oslo	2020-06-20	2020-08-31	0.3
1.72 (1.29-1.97)	R4	Oslo	2020-09-01	2020-10-25	1
1.27 (0.99-1.68)	R5	Oslo	2020-10-26		0.97
0.19 (0.03-0.33)	R1	Rogaland	2020-03-15	2020-04-19	0
0.33 (0.06-0.73)	R2	Rogaland	2020-04-20	2020-08-31	0
1.21 (0.81-1.55)	R3	Rogaland	2020-09-01	2020-10-25	0.85
0.9 (0.34-1.46)	R4	Rogaland	2020-10-26		0.37
1.01 (0.65-1.37)	R1	Møre og Romsdal	2020-03-15	2020-04-19	0.53
0.34 (0.05-0.71)	R2	Møre og Romsdal	2020-04-20	2020-08-31	0
0.68 (0.2-1.17)	R3	Møre og Romsdal	2020-09-01	2020-10-25	0.1
0.65 (0.09-1.39)	R4	Møre og Romsdal	2020-10-26		0.15
0.57 (0.11-0.98)	R1	Nordland	2020-03-15	2020-04-19	0.02
0.66 (0.27-1.02)	R2	Nordland	2020-04-20	2020-08-31	0.04
0.92 (0.47-1.45)	R3	Nordland	2020-09-01	2020-10-25	0.36
0.69 (0.05-1.62)	R4	Nordland	2020-10-26		0.22
0.59 (0.41-0.78)	R1	Viken	2020-03-15	2020-04-19	0
0.83 (0.57-1.06)	R2	Viken	2020-04-20	2020-06-19	0.08
0.94 (0.59-1.24)	R3	Viken	2020-06-20	2020-08-31	0.36
1.17 (0.92-1.42)	R4	Viken	2020-09-01	2020-10-25	0.9
1.34 (1.08-1.56)	R5	Viken	2020-10-26		1

Table 17

Mean (95% CI)	Parameter	County	From	To	Pr(R>1)
0.62 (0.3-0.9)	R1	Innlandet	2020-03-15	2020-04-19	0.01
0.39 (0.09-0.75)	R2	Innlandet	2020-04-20	2020-08-31	0
0.77 (0.28-1.29)	R3	Innlandet	2020-09-01	2020-10-25	0.18
1.38 (0.32-2.03)	R4	Innlandet	2020-10-26		0.82
0.58 (0.21-0.97)	R1	Vestfold og Telemark	2020-03-15	2020-04-19	0.02
0.62 (0.18-0.93)	R2	Vestfold og Telemark	2020-04-20	2020-08-31	0.01
0.98 (0.63-1.44)	R3	Vestfold og Telemark	2020-09-01	2020-10-25	0.45
0.88 (0.21-1.45)	R4	Vestfold og Telemark	2020-10-26		0.35
0.95 (0.37-1.39)	R1	Agder	2020-03-15	2020-04-19	0.46
0.5 (0.18-0.92)	R2	Agder	2020-04-20	2020-08-31	0.01
1.03 (0.21-1.55)	R3	Agder	2020-09-01	2020-10-25	0.62
1.14 (0.35-1.87)	R4	Agder	2020-10-26		0.64
0.65 (0.26-0.94)	R1	Vestland	2020-03-15	2020-04-19	0.01
0.78 (0.34-1.08)	R2	Vestland	2020-04-20	2020-08-16	0.09
0.88 (0.11-2.1)	R3	Vestland	2020-08-17	2020-09-09	0.34
1.14 (0.27-1.76)	R4	Vestland	2020-09-10	2020-10-25	0.7
1 (0.28-2)	R5	Vestland	2020-10-26		0.44
0.98 (0.7-1.33)	R1	Trøndelag	2020-03-15	2020-04-19	0.46
0.63 (0.38-0.91)	R2	Trøndelag	2020-04-20	2020-08-31	0.01
1.2 (0.48-1.63)	R3	Trøndelag	2020-09-01	2020-10-25	0.79
0.97 (0.28-1.71)	R4	Trøndelag	2020-10-26		0.45
1.26 (0.7-1.69)	R1	Troms og Finnmark	2020-03-15	2020-04-19	0.85
0.15 (0.04-0.26)	R2	Troms og Finnmark	2020-04-20	2020-08-31	0
0.74 (0.25-1.27)	R3	Troms og Finnmark	2020-09-01	2020-10-25	0.16
0.86 (0.11-1.86)	R4	Troms og Finnmark	2020-10-26		0.35
1.63 (1.1-2.26)	AMP factor	All			-

Table 18: Hospitalisation probabilities (1/2)

	Until 2020-05-01	Until 2020-06-01	Until 2020-07-01	Until 2020-08-01
0-9 years	0.0001	0.0005	0.001	0.0004
10 - 19 years	0.0004	0.001	0.001	0.001
20 - 29 years	0.006	0.007	0.009	0.009
30 - 39 years	0.013	0.019	0.015	0.018
40 - 49 years	0.018	0.015	0.016	0.017
50 - 59 years	0.043	0.032	0.025	0.030
60 - 69 years	0.059	0.031	0.039	0.035
70 - 79 years	0.087	0.047	0.026	0.029
80+ years	0.317	0.129	0.127	0.025

Table 19: Hospitalisation probabilities (2/2)

	Until 2020-09-01	Until 2020-10-01	Until 2020-11-01	From 2020-11-01
0-9 years	0.0004	0.0004	0.0003	0.001
10 - 19 years	0.001	0.001	0.001	0.001
20 - 29 years	0.014	0.011	0.010	0.007
30 - 39 years	0.014	0.015	0.016	0.014
40 - 49 years	0.013	0.014	0.017	0.016
50 - 59 years	0.025	0.023	0.027	0.028
60 - 69 years	0.015	0.030	0.031	0.036
70 - 79 years	0.028	0.032	0.030	0.035
80+ years	0.042	0.089	0.065	0.107

Table 20: Assumptions

Assumptions	Mean	Distribution	Reference
Mobile Mobility Data			
Telenor coverage	48%		https://ekomstatistikken.nkom.no/
Data updated	November 21th		
Data used in the predictions	November 20th	Fixed	Corrected to preserve population
Model parameters			
Exposed period ($1/\lambda_1$)	3 days	Exponential	Feretti et al 2020
Pre-symptomatic period ($1/\lambda_2$)	2 days	Exponential	Feretti et al 2020
Symptomatic infectious period ($1/\gamma$)	5 days	Exponential	Feretti et al 2020
Asymptomatic, infectious period ($1/\gamma$)	5 days	Exponential	Feretti et al 2020
Infectiousness asympt. (r_{I_a})	0.1	Fixed	Feretti et al 2020
Infectiousness presymp (r_{E_2})	1.25	Fixed	guided by Feretti et al 2020
Prob. asymptomatic infection (p_a)	0.4		Feretti et al 2020
Healthcare			
Time sympt. onset to hospitalisation	9.66 days (before August 1st)/ 7.77 (After August 1st)	Neg. binomial	
Fraction asymptomatic infections	40%	Fixed	Mizumoto et al 2020 20% for the old population, Diamond Princess
% symptomatic and asymptomatic infections requiring hospitalization: 0-9 years 10 - 19 years 20 - 29 years 30 - 39 years 40 - 49 years 50 - 59 years 60 - 69 years 70 - 79 years 80+ years	 0.1% 0.1% 0.5% 1.1% 1.4% 2.9% 5.8% 9.3% 22.3%	Fixed	Saljie et al 2020 corrected for: % of elderly living in elderly homes in Norway (last two age groups) and corrected for presence among positive tested since May 1. Corrected values available in tables 18 and 19
% hospitalized patients requiring ICU Feb - July August -	 16% 7.6%	Fixed	Estimated from "Beredskapsregistret BeredtC19"
Overall hospitalization risk	2.26%	Fixed	Corrected Saljie et al 2020 (adapted to Norwegian demography, used in long-term predictions)
Probability that an admission has been reported on Monday From Sunday From Saturday From Friday From Thursday	 32% 49% 68% 86%	Fixed	Estimated from "Beredskapsregistret BeredtC19"
Probability that an admission has been reported From one day before From two days before From three days before From four days before	 53% 77% 82% 91%	Fixed	Estimated from "Beredskapsregistret BeredtC19"
Probability that a positive laboratory test has been reported From one day before From two days before From three days before From four days before	 6.7% 59% 90% 97%	Fixed	Estimated from MSIS
Probability that a negative laboratory test has been reported From one day before From two days before From three days before From four days before	 16% 74% 92% 98%	Fixed	Estimated from MSIS

Supplementary analysis: EpiEstim estimation of reproduction number based on laboratory-confirmed cases

To complement the results of the metapopulation model, we present estimates of the temporal evolution of the reproduction number in Norway based on an analysis of laboratory-confirmed cases. The primary purpose of this analysis is to provide a more comprehensive perspective on the epidemic situation, taking into account several data sources.
The hospitalisation data are a less biased information source for the number of infections compared to case data because the testing criteria in Norway has changed. For this reason, the present results should be interpreted with caution. During the early part of the period, testing of individuals was mainly based on travel history to areas with an ongoing outbreak. Since the middle of March, testing is recommended for people with an acute respiratory infection. From early May, the testing criteria have been expanded to include less severe symptoms. The analysis of laboratory-confirmed cases does not take into account the effect of imported cases during the early outbreak in Norway; the early results are less reliable than later results when the impact of importations is negligible.

EpiEstim method and assumptions: We estimate the instantaneous reproduction number using the procedure outlined in Thompson et al. (2019). This method, implemented in the EpiEstim R-package, uses a Bayesian approach to estimate the instantaneous reproduction number smoothed over a sliding window of 5 days, see figure 32. For the results to be comparable to those of the metapopulation model, we use the same natural history parameters. We estimate the date of infection for each confirmed case by first estimating the date of symptom onset and then subtracting 5 days for the incubation period. We estimate the date of symptom onset from the empirical delay between onset and testing in the first reported cases. For each case, we draw 100 possible onset dates from the delay distribution; this gives us 100 epi-curves that we use to estimate the reproduction number. The displayed results are the combined results from all these 100 simulated epi-curves. The serial interval was assumed to be 5 days with uncertainty; the serial interval refers to the time between symptom onset between successive cases in a chain of transmission (see https://www.medrxiv.org/content/10.1101/2020.02.03.20019497v2). To account for censoring of observations with onset dates in the last few days we correct the observed data by the mean of a negative binomial distribution with observation probability given by the empirical cumulative distribution of the onset to reporting date distributions. Due to this correction, the results from the last few days are uncertain, as indicated by increasing credible intervals.

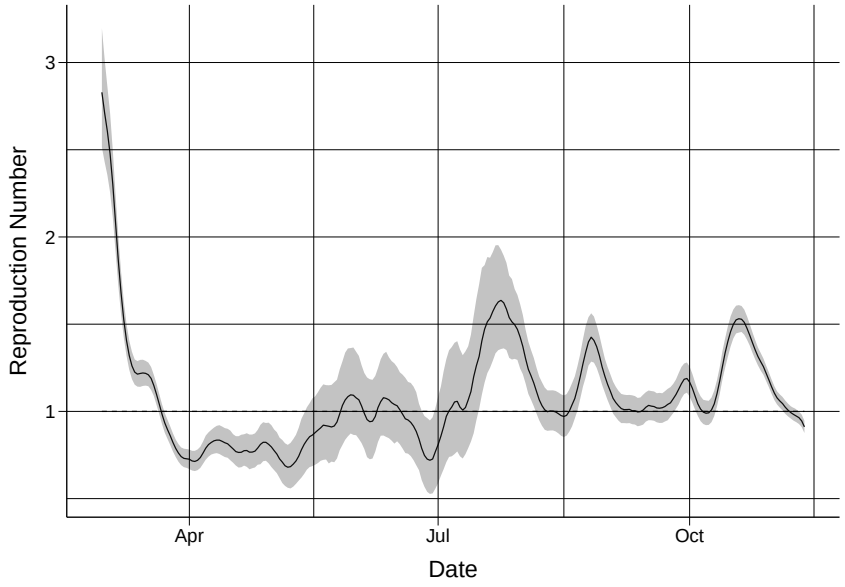


Figure 32: Reproduction number estimated using the R package EpiEstim.

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