

SHORT-TERM PREDICTIONS OF COVID-19 HOSPITALIZATION NUMBERS

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BACKGROUND & MOTIVATION

- The emergency registry **BeredtC19** pulled & merged information from a large number of sources
 - MSIS, Norwegian Pandemic Registry, Norwegian intensive care registry, Sysvak etc....
- Speed of update was remarkable
 - Confirmed positive tests usually updated within days of testing
 - Hospitalizations with similar speed, though perhaps some more lag in particular cases
- **Amazing job!** by so many people to get the registry up and running

BACKGROUND & MOTIVATION

- The **NIPH modelling team** did an excellent job from the very start of the pandemic in computing R-numbers, both regionally and nationally, providing long-term scenarios and also short-term predictions.
- Their work was presented in regular report, as well as in answers to numerous “oppdrag” (requests) from the Ministry of Health and Care Services as well as the Norwegian Directorate of Health.
- Various other groups/teams provided solid and frequently updated reports on the development, both for the use by NIPH as well as for use by the press.



BACKGROUND & MOTIVATION

Standard Reporting:
Incidences
Weekly totals
Various summary statistics
Etc.!

Research papers:
Vaccine efficacy
Vaccine side effects
Intervention effects
Etc.!

Simulation models for spread of infection:
Computationally very intensive
Can include lots of factors
Can provide future “scenarios”
Etc.!

- However, in between the “standard reporting”, regular research, and heavy simulation models there is room & need for data-driven models in surveillance.
- Speed is a decisive factor.

STATISTICAL MODELS FOR SHORT-TERM PREDICTION AND CONTROL

- **Extremely useful to inform day-to-day decisions in pandemic control**

Rationale

- “Standard” pandemic simulation-based long-term modelling
 - Complex, very sensitive to assumptions, but also very flexible
 - Computationally very heavy and time-consuming
 - Very useful to generate long term “scenarios”
 - Needed for short-term modelling?
- Short-term models
 - Need not worry quite that much about feedback loops, non-linearity etc.
 - Short-term models can be fast and “easy” to update on a regular basis
 - Based on combinations of “regular” statistical models... huge speed gains
 - Can be seen as extensions of standard reporting... or simplifications of simulation models

BACKGROUND & MOTIVATION, ASTRAZENECA-ANALYSES 2021

Oppdrag fra HOD om koronavaksinasjonsprogrammet nr. 21

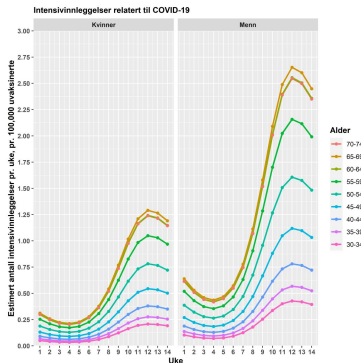


Fig 1: Resultatene fra prediksjonsmodellen er her vist, avgrenset til 2021. Beregningene er vist separat for kjønn og alderskategorier. Estimert Covid-19-relaterte intensivinnleggelser er beregnet som forventet antall intensivinnleggelser pr. uke pr. 100,000 uvaksinerte personer. Vaksinerte er tatt ut av modellen etter vaksinerings.

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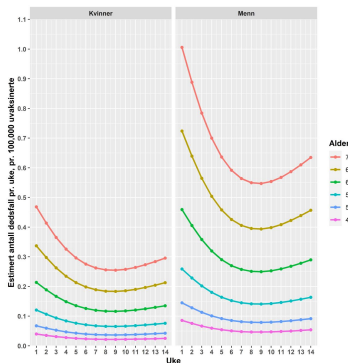
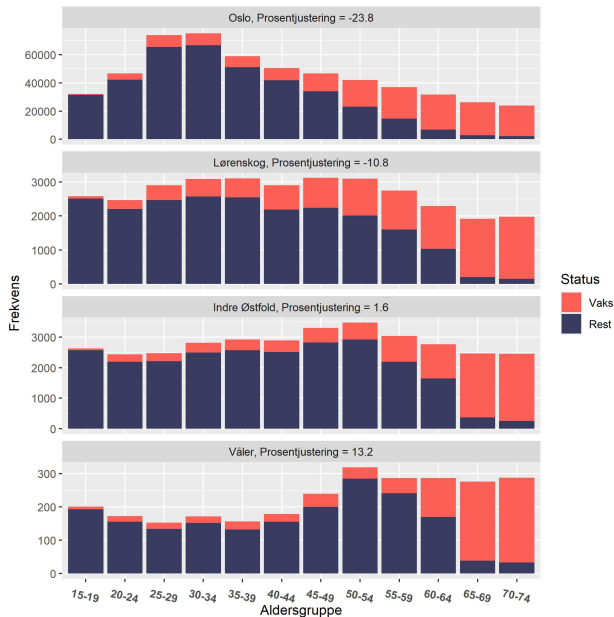


Fig 1: Resultatene fra prediksjonsmodellen er her vist, avgrenset til 2021. Beregningene er vist separat for kjønn og alderskategorier. Estimert Covid-19-relaterte dødelighet er beregnet som forventet antall dødsfall pr. uke pr. 100,000 uvaksinerte personer. Vaksinerte er tatt ut av modellen etter vaksinerings.

BACKGROUND & MOTIVATION, VACCINE DISTRIBUTION



SHORT-TERM PREDICTIONS

Objective

- Predict hospitalizations and ICU admissions from current infection rates
 - “Infection” means positive PCR test (MSIS)
 - Hospitalizations have covid-19 as main cause

FOCUS ON SURVEILLANCE

Observed infections up until today



Expected number of hospitalizations in the coming weeks



Expected number of ICU hospitalizations in the coming weeks

How valid is this relationship?

- Quite stable, *as long as conditions remain the same*

- The number of infections are high; relatively stable estimates of infections
- An “undisturbed” pandemic is exponential (over modest time intervals)
- The relationship between infections and hospitalizations is quite reliable and can be estimated over a fairly large time interval

Predictions 2–3 weeks into the future will provide you with some time to implement interventions

VARIABLES TO BE USED IN THE MODEL

- Age (5-year intervals)
- Vaccination Status: Unvaccinated, Vaccinated (1 or 2 doses), Vaccinated (2+booster)
- Risk group (risk of serious development of infection)
- Sex
- **Calendar Time**
- (Municipality, county)

NECESSARY MODEL COMPONENTS

① Infection prediction:

of infections until today → # of infections in coming weeks

② Estimated probability: infection → hospital admission

③ Estimated probability:

admitted to hospital same days as positive PCR test

④ Estimated time distribution:

positive test → hospital admission later than positive PCR test

⑤ Estimated time distribution: hospital length of stay if admitted

⑥ Estimated probability: hospital admission → ICU admission

⑦ Estimated time distribution: hospital admission → ICU admission

⑧ Estimated time distribution: length of stay in ICU

... and all of these may depend on the listed covariates(!)

... in particular, they may change over time...

SHORT-TERM PREDICTIONS, STARTUP TIMELINE, 2021

- Tuesday 3 Aug, first meetings about the project (initiated by Geir Bukholm)
- Wednesday 4 Aug, I sent the data request in the morning



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- Monday 9 Aug at 09:00, temporary results presented to the Minister of Health and the political heads of the Health Ministry



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- Monday 9 Aug at 09:00, temporary results presented to the Minister of Health and the political heads of the Health Ministry
- Wednesday 11 Aug: New presentation of results to the Minister of Health. Most of the results ready
- Thursday 12 Aug: Camilla presented the essence of it at a government conference deciding on whether re-opening the country was possible
- Friday 13 Aug: Government press conference about re-opening plans



PROBLEM

The roof of my summer cabin wasn't entirely waterproof at the moment...



POISSON REGRESSION FOR THE NUMBER OF POSITIVE TESTS

$$\log(\lambda) = \text{sex} + \text{risk group} + (\text{age} * \text{vaccination status}) / \text{testdate}$$

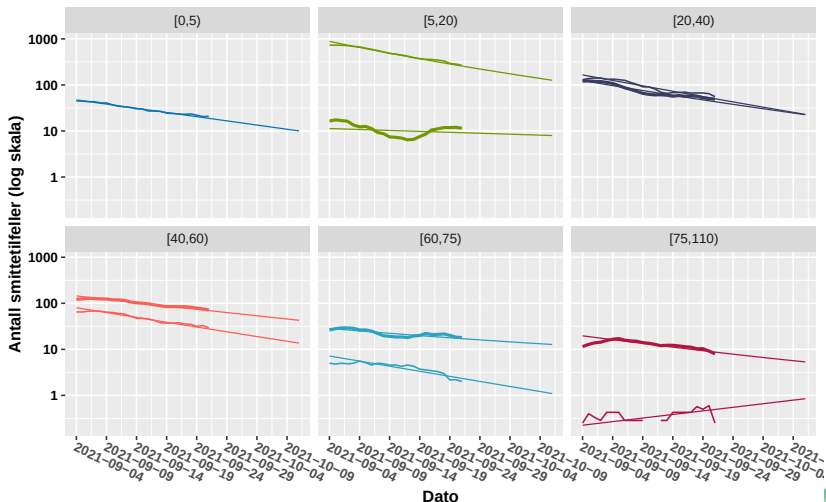
λ = expected number of positive tests

- sex: Two levels
- risk group: Three levels
- age: 5-year groups
- vaccination status: Two levels
- testdate: Three previous weeks for fitting, three coming weeks for predictions
- (municipality, county)

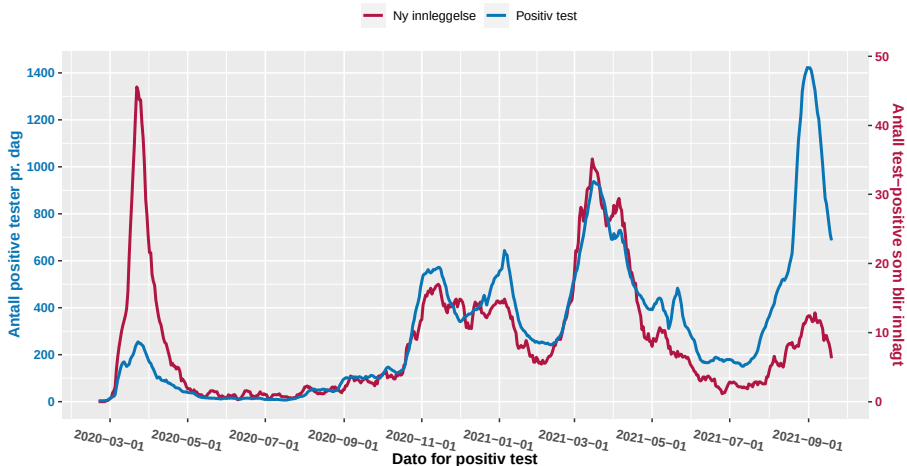
Plus: A weight variable, with weights from 0.1 up to 1 from the earliest to the latest date when fitting (or variants thereof)

OBSERVED AND MODEL EXTRAPOLATED NUMBER OF POSITIVE TESTS

Vaksinestatus — Uvaksinert — DelFullvaksinert



POSITIVE TESTS AND HOSPITALIZATIONS



Blue curve: Number of positive tests on a given day

Red curve: Number of those who at some point gets admitted to a hospital

FROM POSITIVE TESTS TO NEW HOSPITALIZATIONS

Probability of hospitalization

- Probability of hospitalization depends on
 - sex
 - age
 - risk group
 - vaccination status
 - calendar date
 - (municipality, county)

FROM POSITIVE TESTS TO NEW HOSPITALIZATIONS

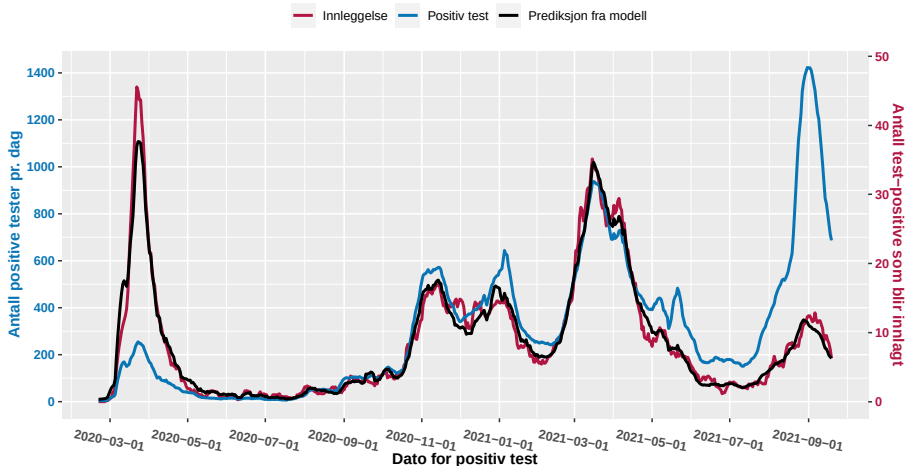
Probability of hospitalization

Binomial family GAM (Generalized Additive Model) with a smooth term $s()$

$$\begin{aligned} &\text{logit}(P(\text{hospitalized} \mid \text{positive test})) \\ &= \text{sex} + \text{age} + \text{risk group} + \text{vaccination status} + s(\text{testdate}) \end{aligned}$$

- Hopefully, $s(\text{testdate})$ does not change quickly
- Variants with interactions also relevant
 - $\text{age} * \text{vaccination status}$ can be relevant, but isn't very strong
 - Changes in testing strategies specific to age groups, e.g. school testing, can introduce interactions between age and $s(\text{testdate})$

POSITIVE TESTS AND HOSPITALIZATIONS



- Checking the model fit on the number of test-positives being hospitalized

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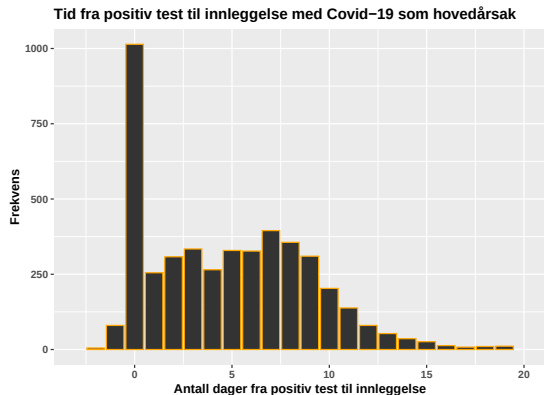
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... in particular, they may change over time...

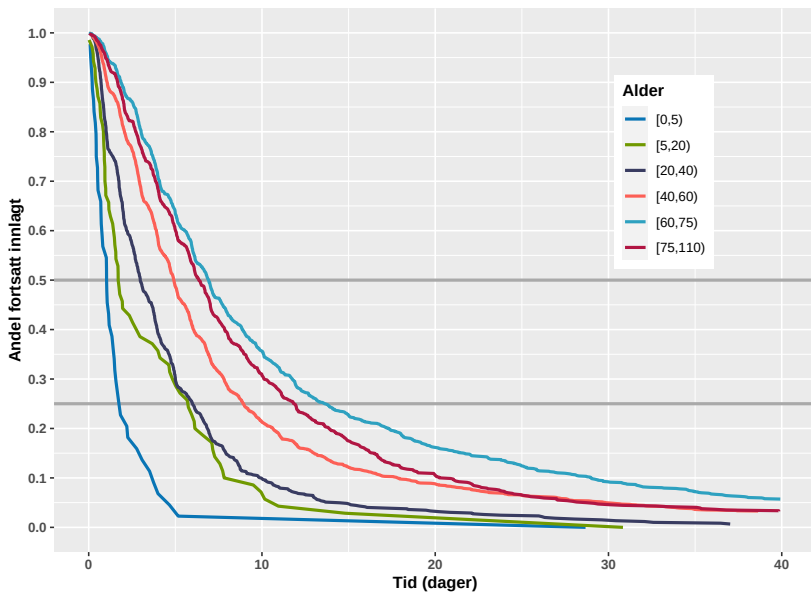
TIME FROM POSITIVE TEST TO HOSPITALIZATION

- Conditional on being hospitalized, what is the distribution of time until hospitalization?



Zero inflation: Some people get ill, get hospitalized, and *then* tested

“SURVIVAL” DISTRIBUTIONS FOR LENGTH OF HOSPITAL STAY

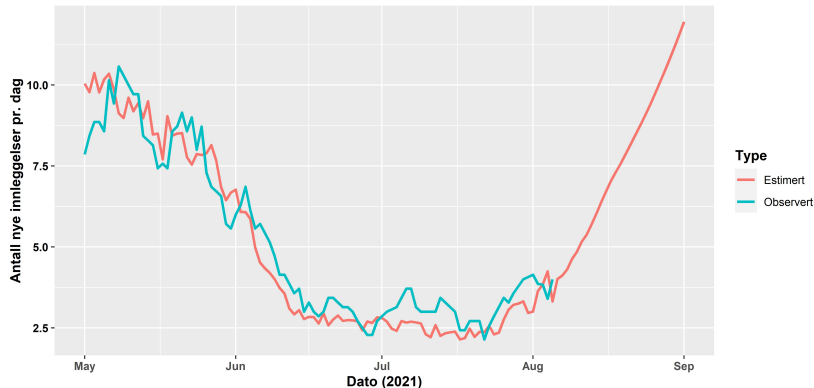


OBSERVED AND ESTIMATED NUMBER OF NEW HOSPITALIZATIONS

First predictions

Totalt antall nye innleggelser, observert og modellestimert

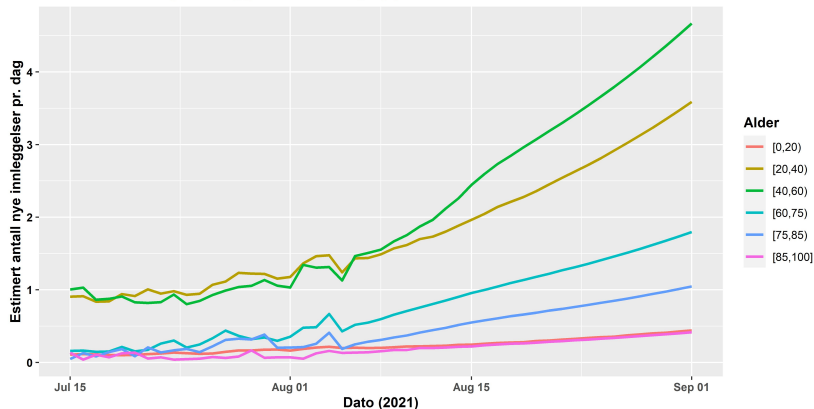
Observert er 7 dagers glidende gjennomsnitt



OBSERVED AND ESTIMATED NUMBER OF NEW HOSPITALIZATIONS

First predictions

Estimert antall nye innleggelser i aldersgrupper

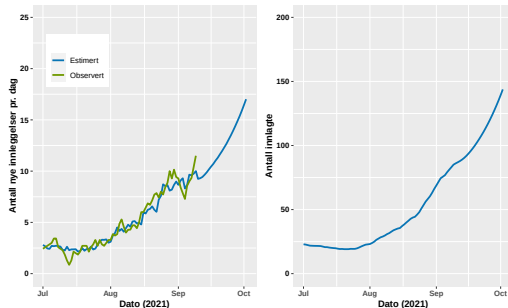


OBSERVED AND ESTIMATED NUMBER OF NEW HOSPITALIZATIONS

Predictions 12 Sept, expected hospitalizations



Estimert antall innleggelser, totalt

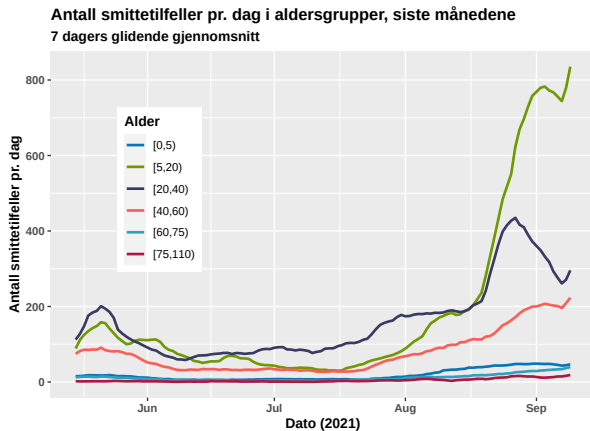


- Merk et betydelig fall i forhold til tidligere framskrivninger.

OBSERVED NUMBER OF NEW HOSPITALIZATIONS

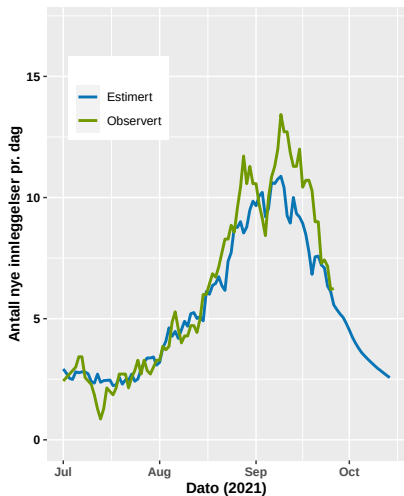
12 Sept, number of positive tests

Registrerte positive tester, i aldersgrupper

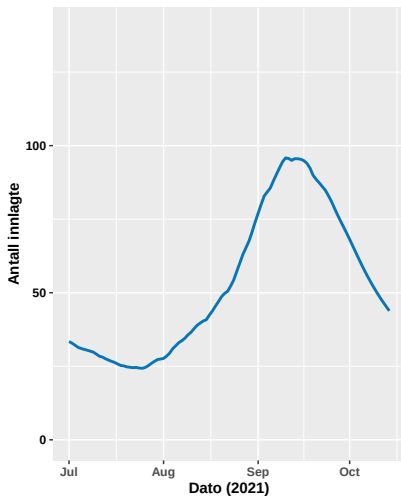


ESTIMATED HOSPITALIZATIONS, TOTAL

New hospitalizations



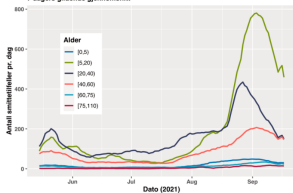
In hospital





CORONAVIRUSET | Tall | Titler | Vakanser | Siste | Spør oss | Artikler

Antall smittetilfeller pr. dag i aldersgrupper, siste månedene 7 dagers glidende gjennomsnitt



GALEK: Disse grafene viser at smitten går nedover i aldersgruppene 0-20 og 20-40. Dette er en klar vaksineeffekt. Gruppen 40-60 går svakt nedover. Dette er en gruppe som har vært vaksinert i en stund, som forklarer hvorfor den ikke går så brått nedover. 75-110 år: dette er den eneste som går svakt oppover, men stigningen er marginal. (Info: Strykerhuset)

Dette er grafen som kan åpne Norge

De siste analysene fra FHI viser at tiden snart er inne for å åpne, sier smitteverndirektøren.

Av LINA FAUSKO og MARTHA C. S. HOLMES
Oppdatert 21. september



Dette viser grafen

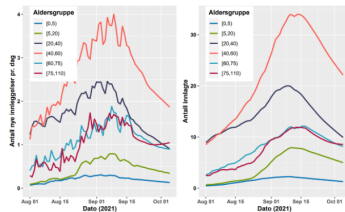
Antall smittetilfeller brutt ned på alder:

I alle aldersgrupper, er det en knekk, bortsett fra 75-110 år.

- Aldersgruppe 0-20: smitten går tydelig nedover – det er en kombinasjon av at ungdommer blir vaksinert og at smitten går ned som følge av befolkningsimmunitet
- 20-40 år: sterk nedover, som er en klar vaksineeffekt
- 40-60 år: svakt nedover. Dette er en gruppe som har vært vaksinert i en tid, som forklarer hvorfor den ikke går så brått nedover
- 75-110 år: dette er den eneste som går svakt oppover, men stigningen er marginal
- Estimert antall innleggelser, går veldig tydelig ned

GALEK: "Antall nye innleggelser per dag i aldersgrupper"

Estimert antall innleggelser, etter alder



SYNKE: Denne grafen viser for første gang antall forventede innleggelser fordelt på alder. Til venstre ser...



Korttidsframskrivninger sykehusinnleggelser

Dato: 28. september 2021

Data:

- Data ekstrahert fra BeredC19 28/9 kl. 20:00.
Siste inkluderte dag er 26/9.
- Smitte er her definert som registrert positiv test.
- Innleggelser er avgrenset til de med covid-19 som hovedårsak.

Modellbeskrivelse:

En kort beskrivelse av modellene finnes på [slutten av rapporten](#).

- Separate reports (about 3 times a week)

Korttidsframskrivninger: <https://www.fhi.no/sv/smittsomme-sykdommer/corona/koronavirus-modellering/>

- ... with all figures in the official NIPH color palette!

TOO MUCH DATA?



- This type of modelling indeed seems useful...
- 2-3 weeks warning is probably enough in most cases
- However, model structure may need frequent updates/modifications over time

CONCLUSIONS II

New roof as well...

